

(12) **United States Patent**  
Steuer et al.

(10) **Patent No.:** **US 9,363,892 B2**  
(45) **Date of Patent:** **Jun. 7, 2016**

(54) **CIRCUIT ASSEMBLY AND  
CORRESPONDING METHODS**

(71) Applicant: **Google Technology Holdings LLC**,  
Mountain View, CA (US)

(72) Inventors: **Paul R Steuer**, Hawthorn Woods, IL  
(US); **Mark A Barabolak**, Elmhurst, IL  
(US); **Patrick J Cauwels**, South Beloit,  
IL (US); **Timothy J Sutherland**,  
Gurnee, IL (US)

(73) Assignee: **Google Technology Holdings LLC**,  
Mountain View, CA (US)

(\*) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 319 days.

(21) Appl. No.: **13/946,351**

(22) Filed: **Jul. 19, 2013**

(65) **Prior Publication Data**

US 2015/0022986 A1 Jan. 22, 2015

(51) **Int. Cl.**  
**H05K 1/14** (2006.01)  
**H05K 1/11** (2006.01)  
**H05K 1/02** (2006.01)  
**H05K 5/00** (2006.01)  
**H05K 3/36** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC ..... **H05K 1/144** (2013.01); **H05K 1/023**  
(2013.01); **H05K 1/111** (2013.01); **H05K 3/368**  
(2013.01); **H05K 5/0017** (2013.01); **H05K**  
**9/0022** (2013.01); **H05K 1/145** (2013.01);  
**H05K 3/341** (2013.01); **H05K 2201/042**  
(2013.01); **H05K 2201/09072** (2013.01); **H05K**  
**2201/10371** (2013.01); **H05K 2201/10969**  
(2013.01); **H05K 2201/2036** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H05K 1/144; H05K 1/145; H05K 1/119;  
H05K 1/028

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,460,817 A \* 7/1984 Tani et al. .... 219/85.16  
4,661,792 A \* 4/1987 Watkins ..... H05K 1/145  
336/192

(Continued)

FOREIGN PATENT DOCUMENTS

EP 1168445 A1 1/2002  
EP 1471604 A1 10/2004

(Continued)

OTHER PUBLICATIONS

Invitation to Pay Additional Fees and Partial Search Report for PCT  
Patent Application No. PCT/US2014/047074, mailed on Jan. 8,  
2015, 6 pages.

(Continued)

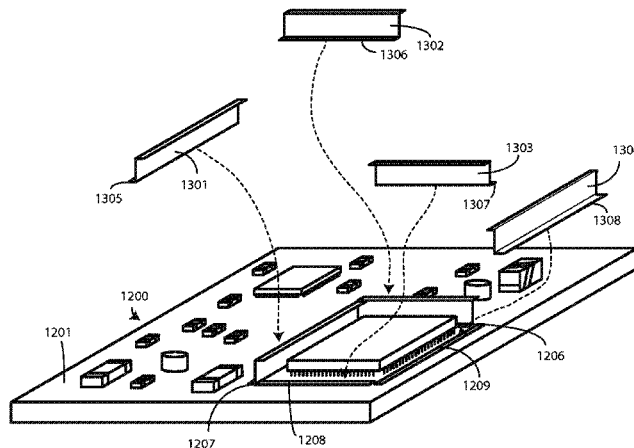
*Primary Examiner* — Jeremy C Norris

*Assistant Examiner* — Nathan Milakovich

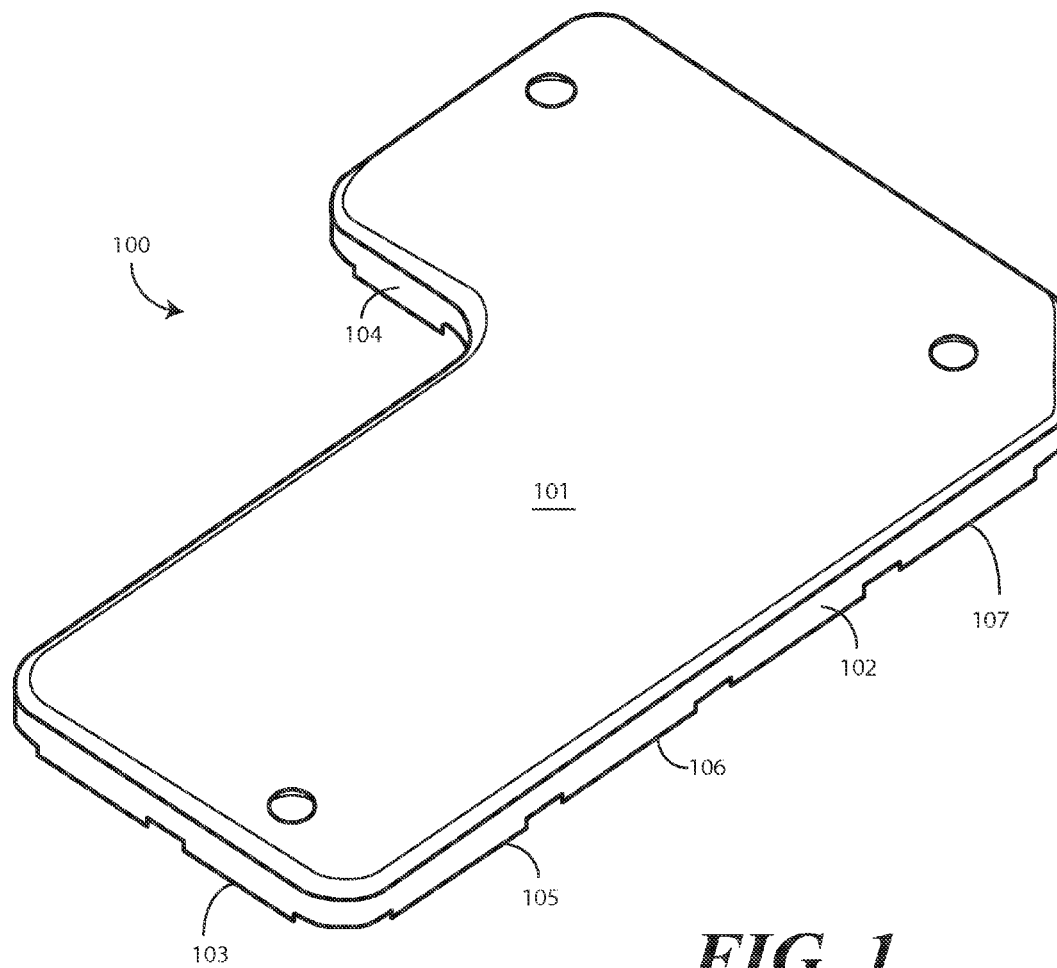
(57) **ABSTRACT**

A circuit assembly (1800) includes a first circuit substrate  
(1200) defining a first major face (1201) and a second circuit  
substrate (1500) defining a second major face (1502). A plu-  
rality of electrical components (1203,1204,1205) can be dis-  
posed on one or more of the first major face or the second  
major face. One or more substrate bridging members (1301,  
1302,1303,1304) are disposed between the first circuit sub-  
strate and the second circuit substrate. Each substrate bridg-  
ing member can define a unitary structure having a first end  
bonded to the first major face and a second end bonded to the  
second major face to bridge the first circuit substrate and the  
second circuit substrate.

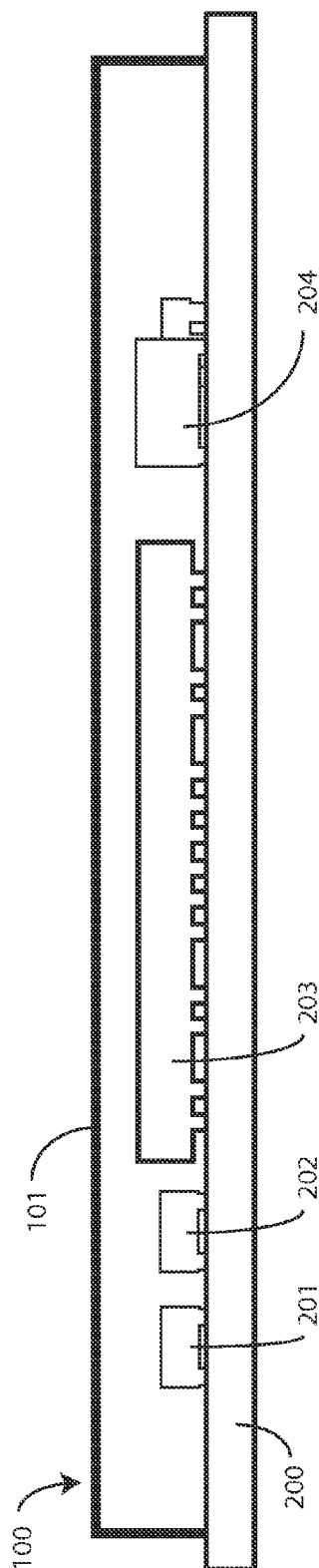
**20 Claims, 23 Drawing Sheets**



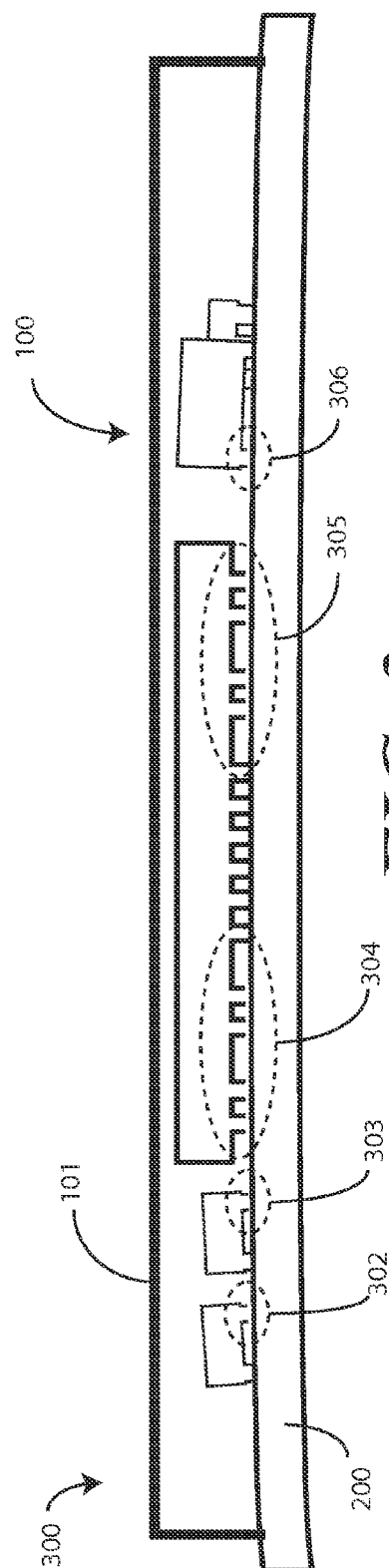
(51)	<b>Int. Cl.</b>		2011/0248389 A1 *	10/2011	Yorita et al. ....	257/659
	<b>H05K 9/00</b>	(2006.01)	2014/0233191 A1 *	8/2014	Kakehashi ....	H05K 1/144
	<b>H05K 3/34</b>	(2006.01)				361/729
			2014/0345123 A1 *	11/2014	Chamberlin et al. ....	29/830
			2014/0347000 A1 *	11/2014	Hamann et al. ....	320/103
(56)	<b>References Cited</b>		2015/0022978 A1 *	1/2015	Steuer et al. ....	361/749
			2015/0201496 A1 *	7/2015	Liao et al. ....	361/721
	<b>U.S. PATENT DOCUMENTS</b>					
	6,608,756 B2 *	8/2003	Higashida et al. ....			361/748
	6,712,620 B1 *	3/2004	Li et al. ....			439/63
	6,917,526 B2 *	7/2005	Ajioka et al. ....			361/816
	7,258,549 B2 *	8/2007	Asahi et al. ....			439/66
	7,365,992 B2	4/2008	Lee			
	7,489,524 B2 *	2/2009	Green		H05K 3/366	
						361/803
	7,557,307 B2 *	7/2009	Nishizawa et al. ....			174/384
	7,643,305 B2 *	1/2010	Lin			361/749
	7,729,131 B2	6/2010	Wang et al.			
	7,952,889 B2 *	5/2011	Chao			361/816
	8,159,829 B2 *	4/2012	Mori et al.			361/761
	8,363,422 B2 *	1/2013	Sakinada et al.			361/799
	2011/0063814 A1 *	3/2011	Nimura et al.			361/796
					<b>FOREIGN PATENT DOCUMENTS</b>	
			EP	2627160 A1 *	8/2013	
			GB	14518 *	6/1913	
			WO	WO 2008059643 A1 *	5/2008	H05K 1/14
			WO	2015/009957 A2	1/2015	
					<b>OTHER PUBLICATIONS</b>	
					International Search Report and Written Opinion for PCT Patent	
					Application No. PCT/US2014/047074, mailed on Mar. 10, 2015, 16	
					pages.	
					* cited by examiner	



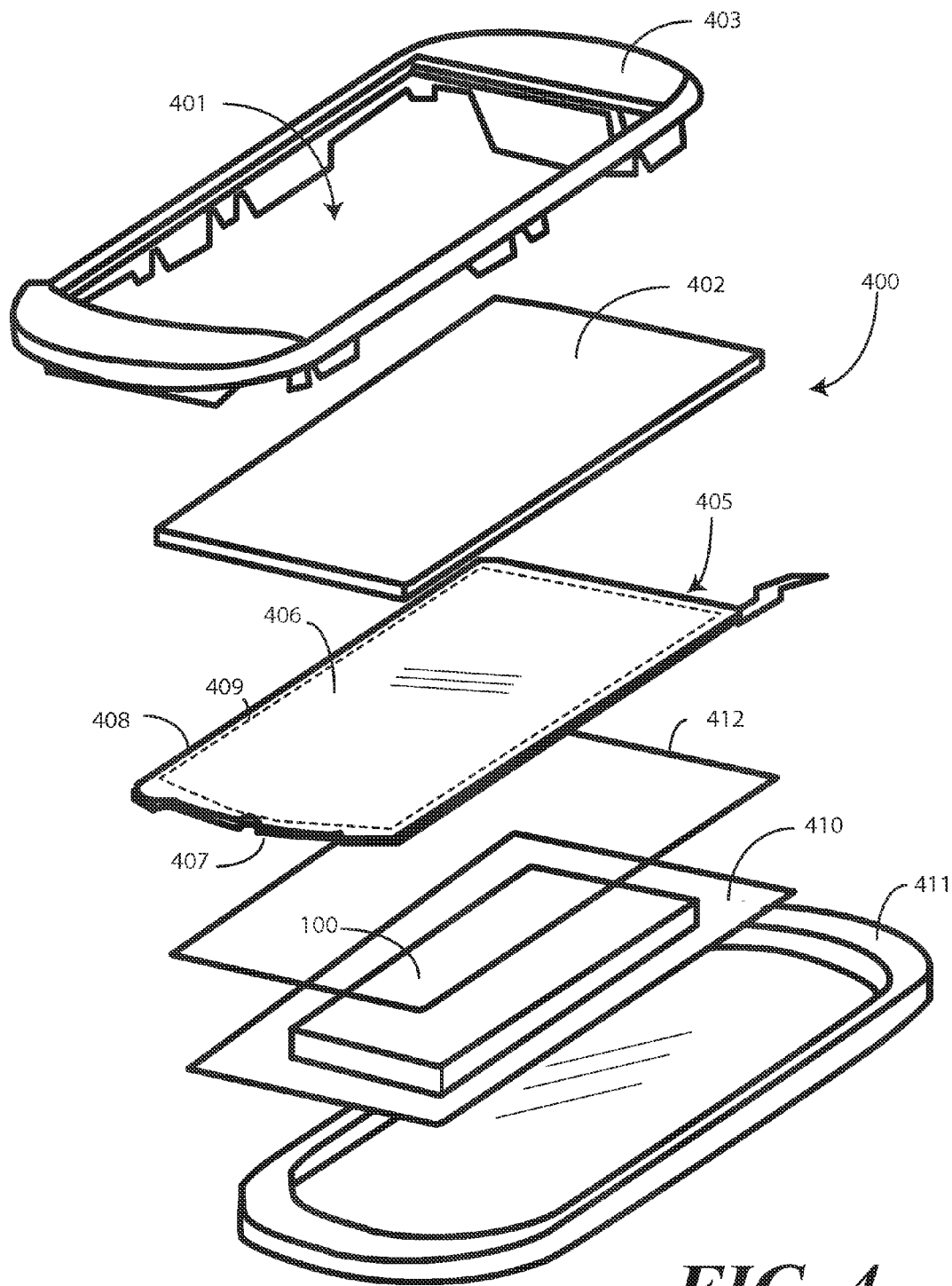
**FIG. 1**  
(Prior Art)



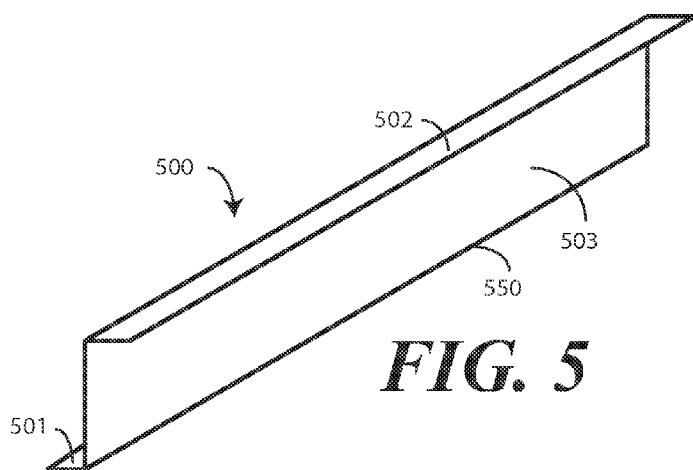
**FIG. 2**  
(Prior Art)



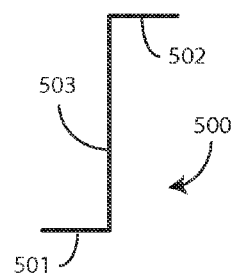
**FIG. 3**  
(Prior Art)



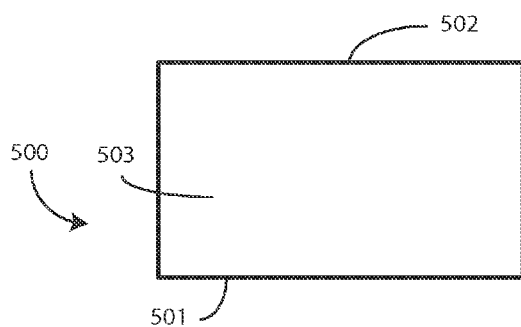
**FIG. 4**  
(Prior Art)



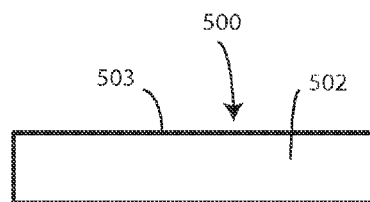
**FIG. 5**



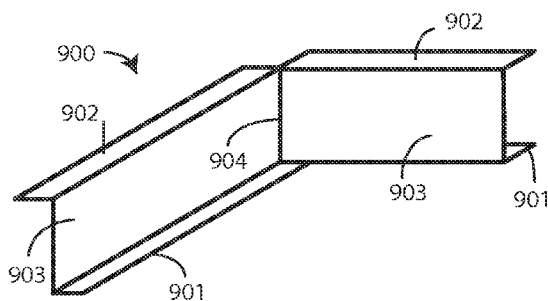
**FIG. 6**



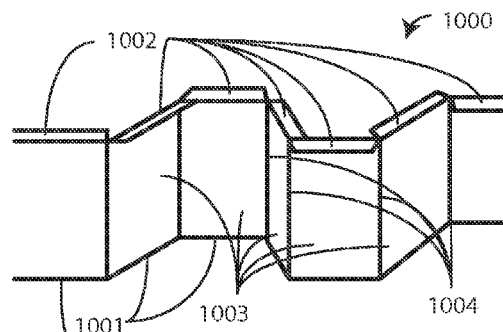
**FIG. 7**



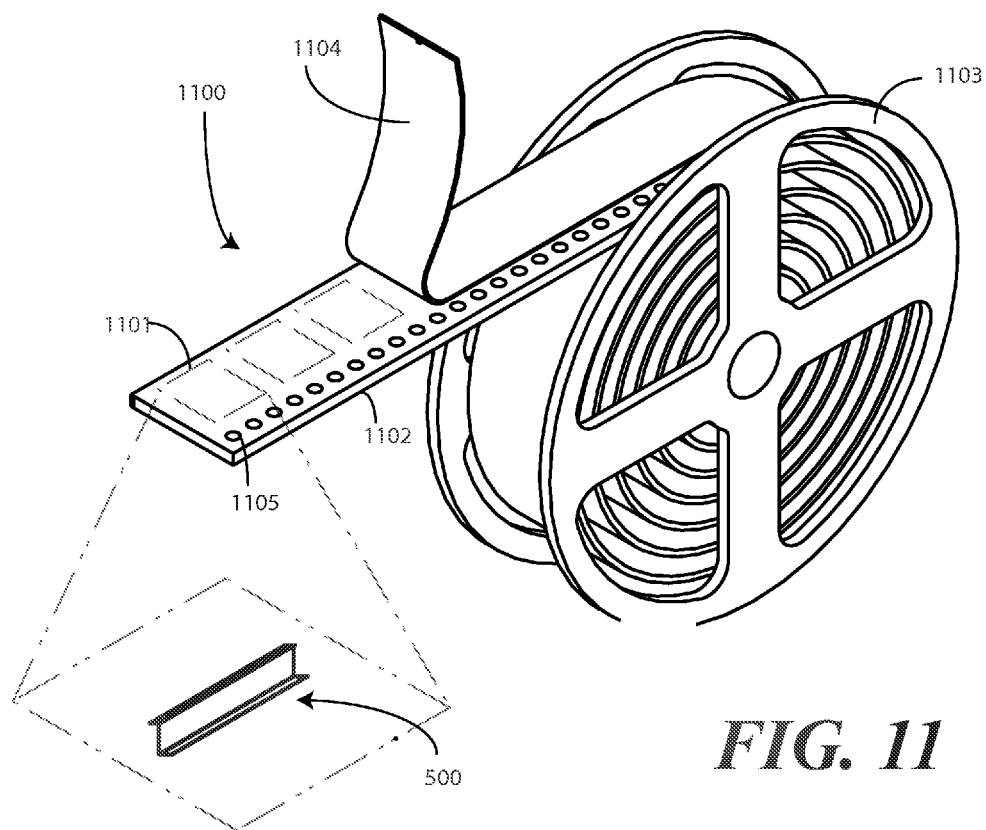
**FIG. 8**



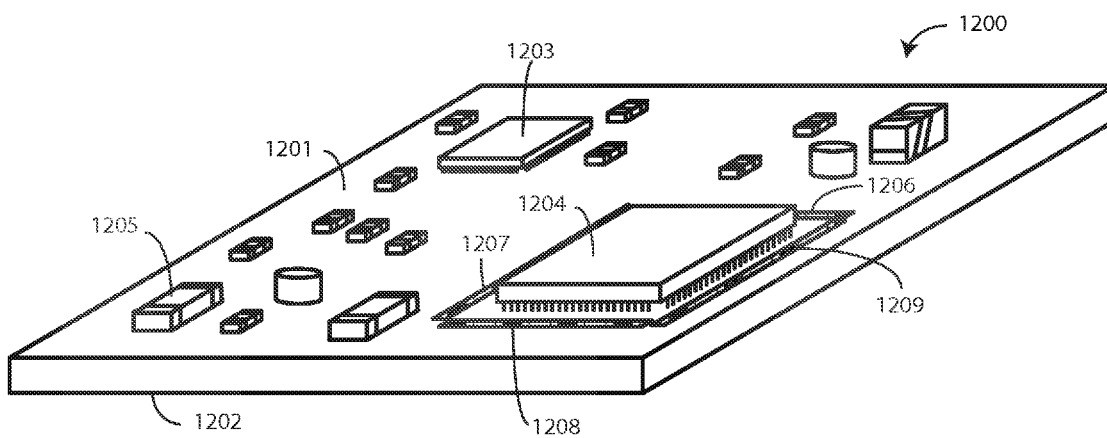
**FIG. 9**



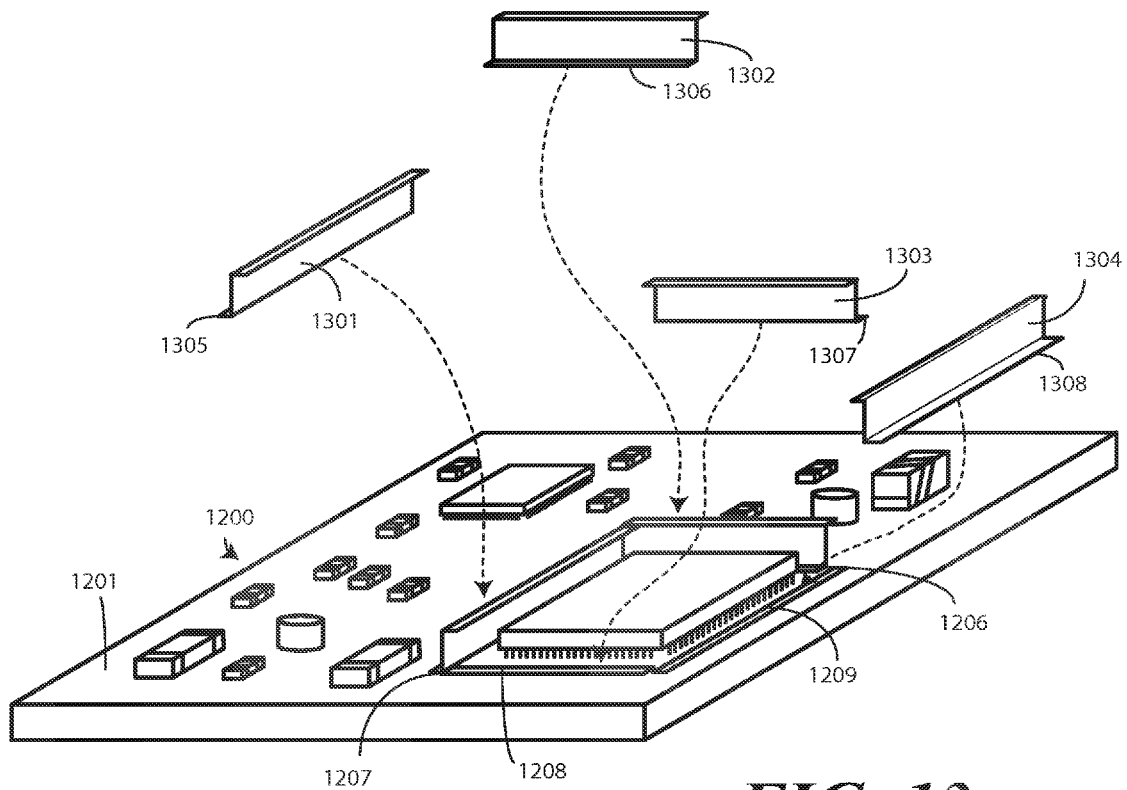
**FIG. 10**



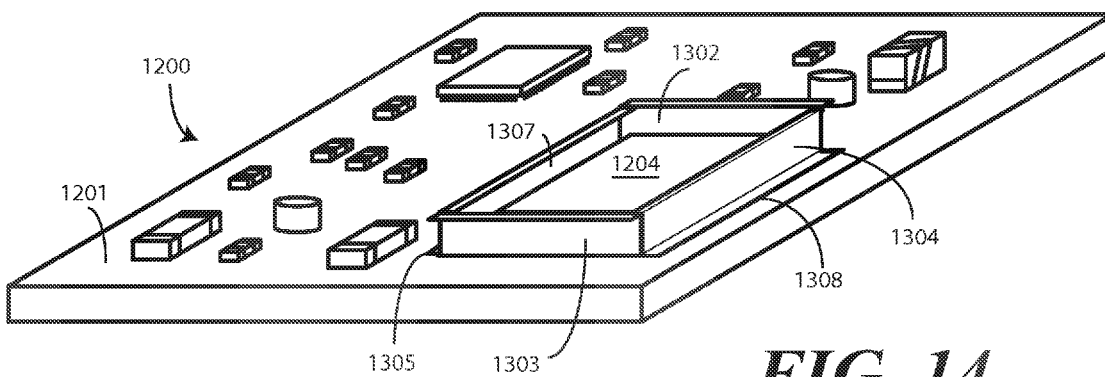
**FIG. 11**



**FIG. 12**

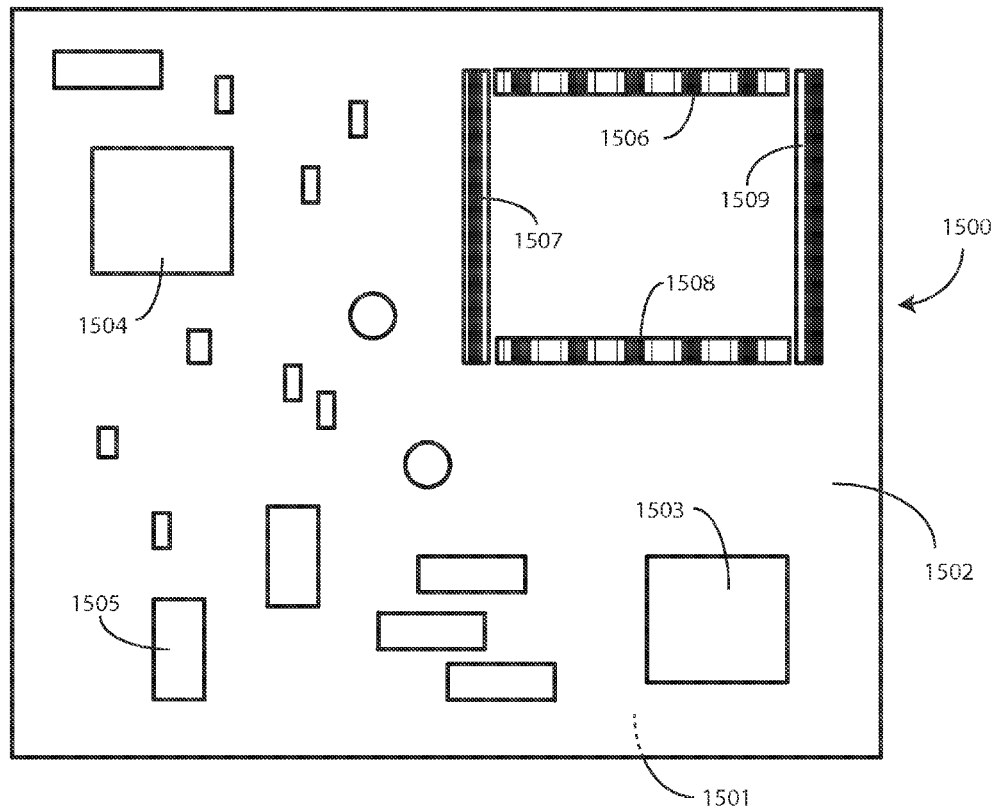


**FIG. 13**

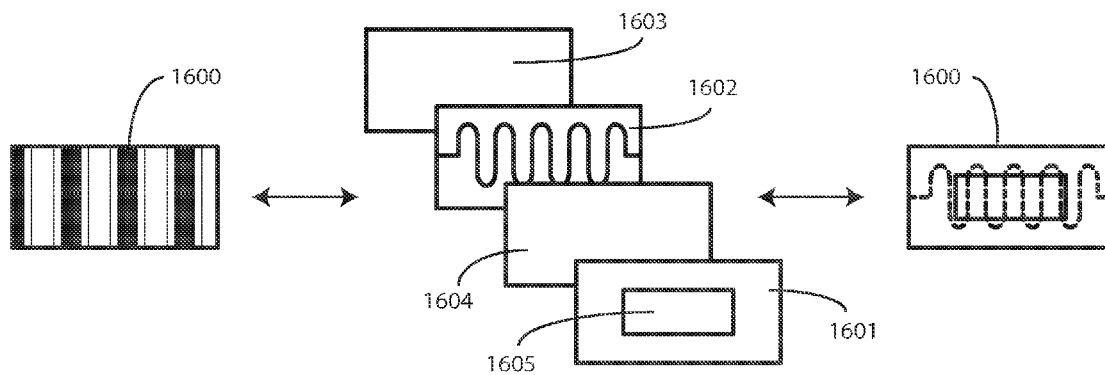


**FIG. 14**

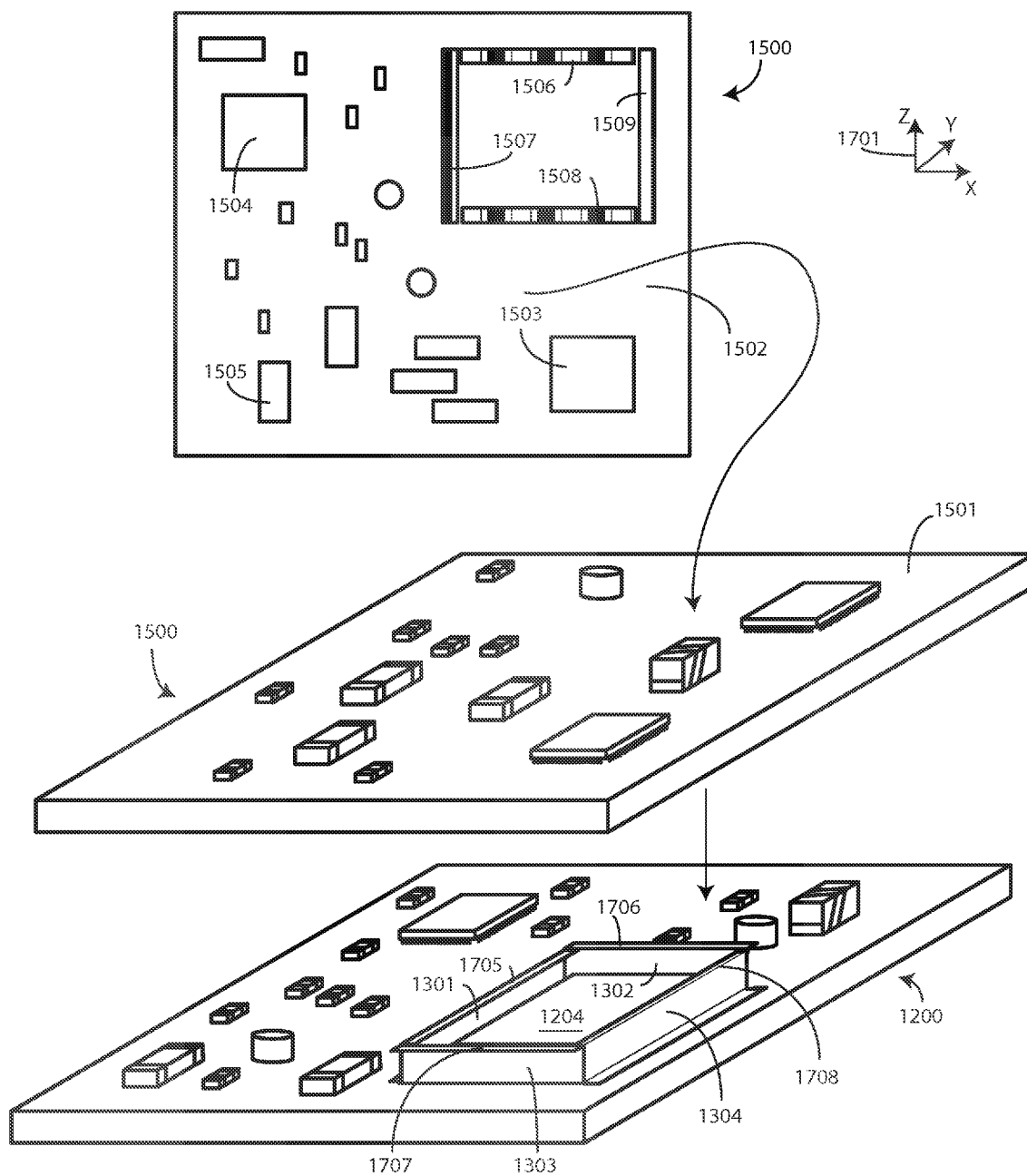




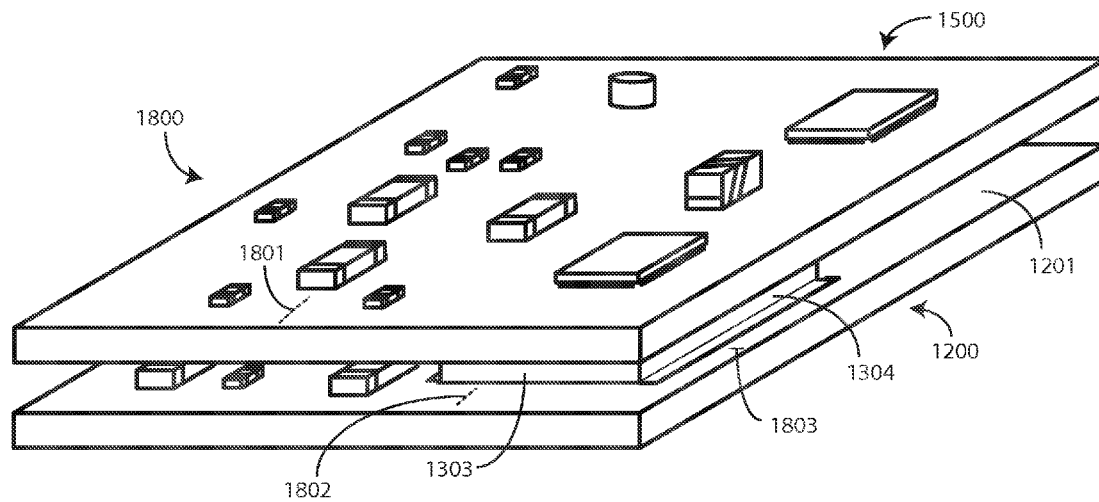
**FIG. 15**



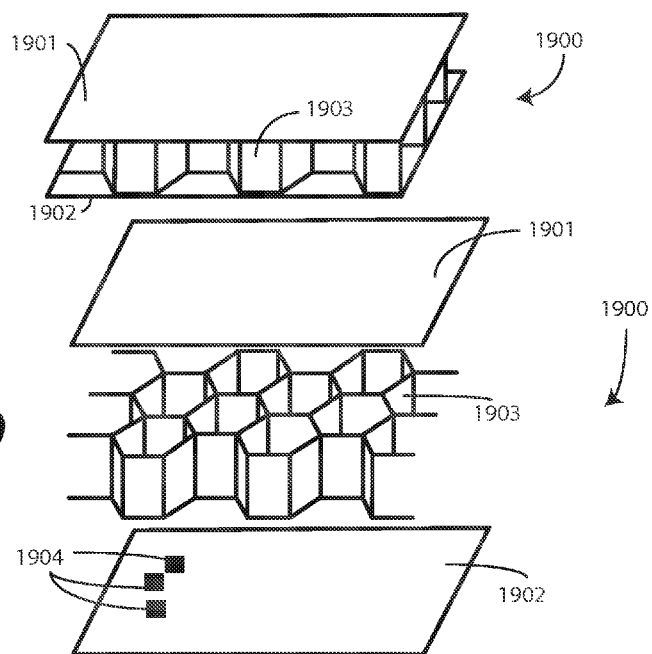
**FIG. 16**



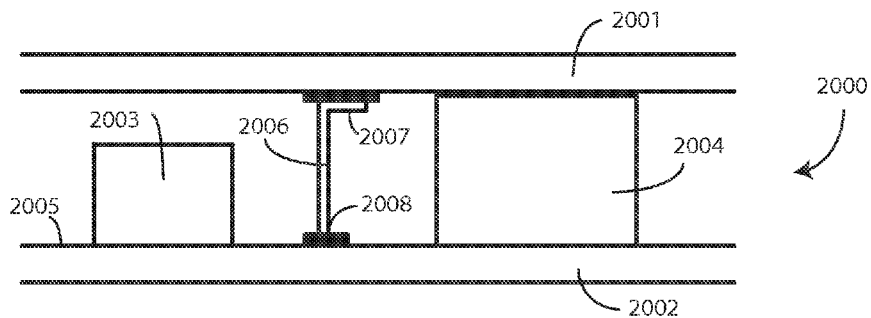
**FIG. 17**



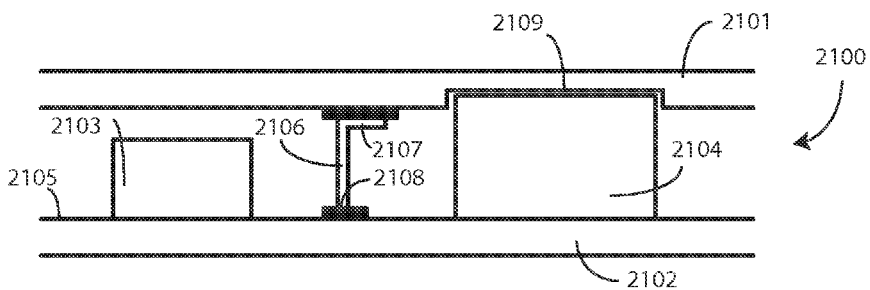
**FIG. 18**



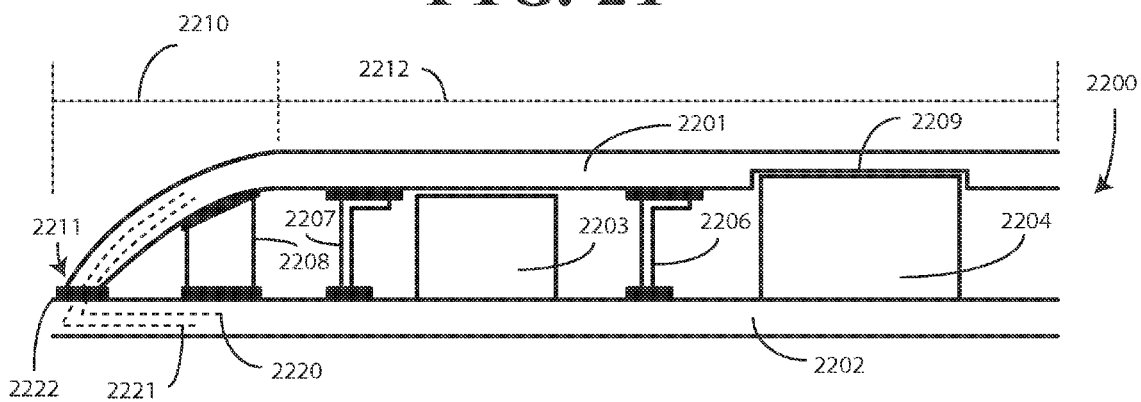
**FIG. 19**



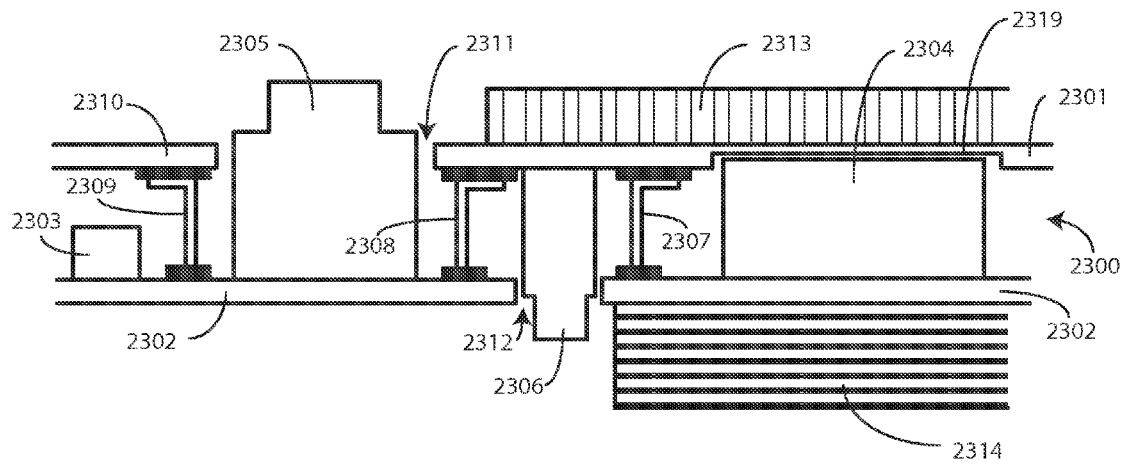
**FIG. 20**



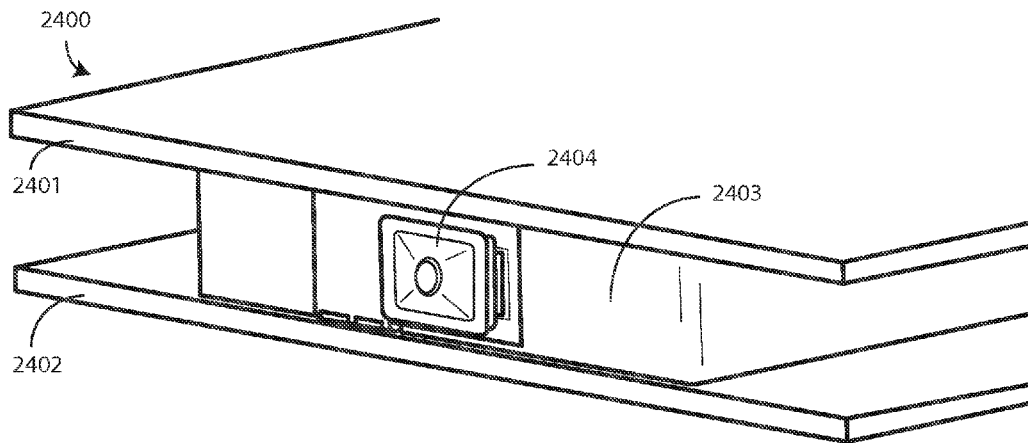
**FIG. 21**



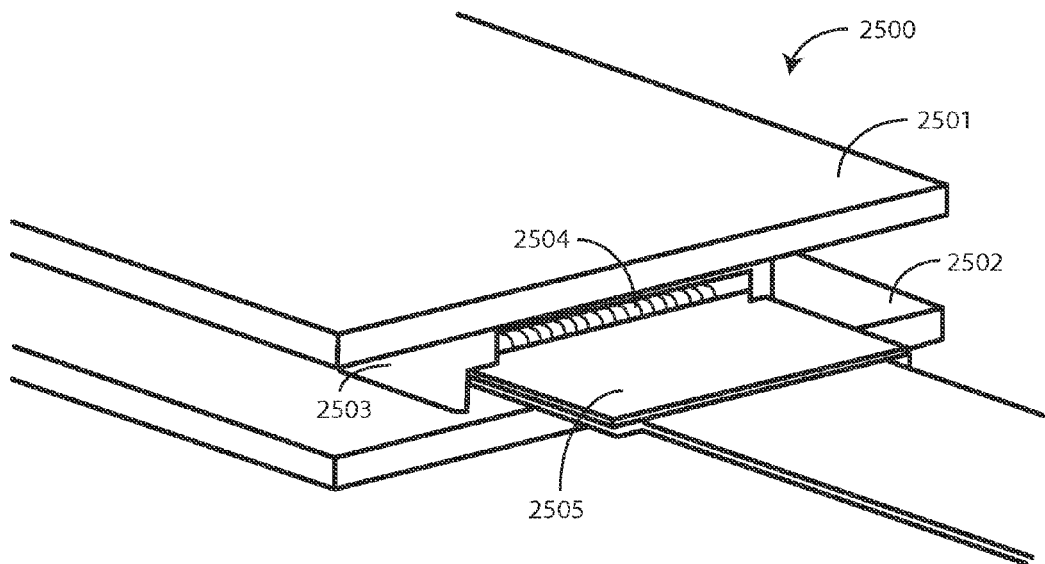
**FIG. 22**



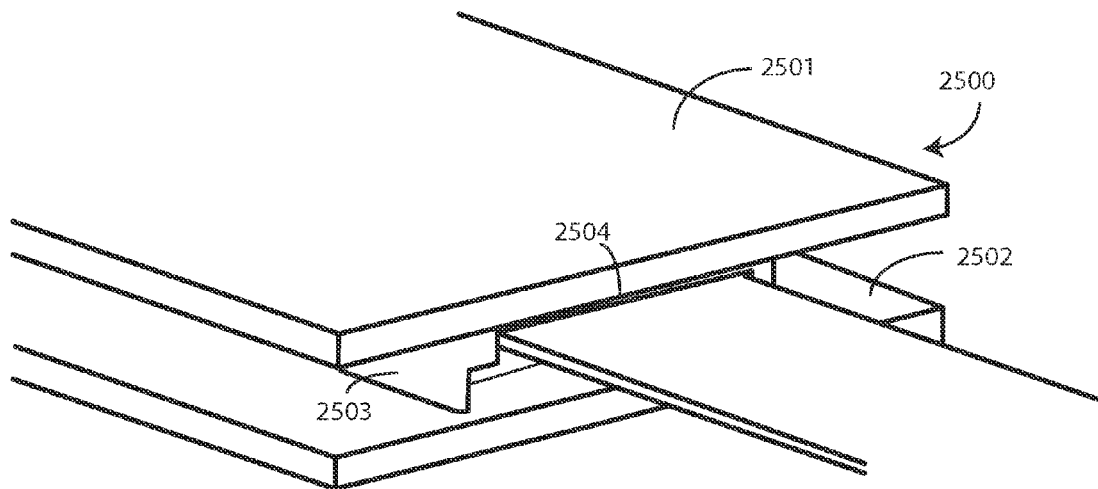
**FIG. 23**



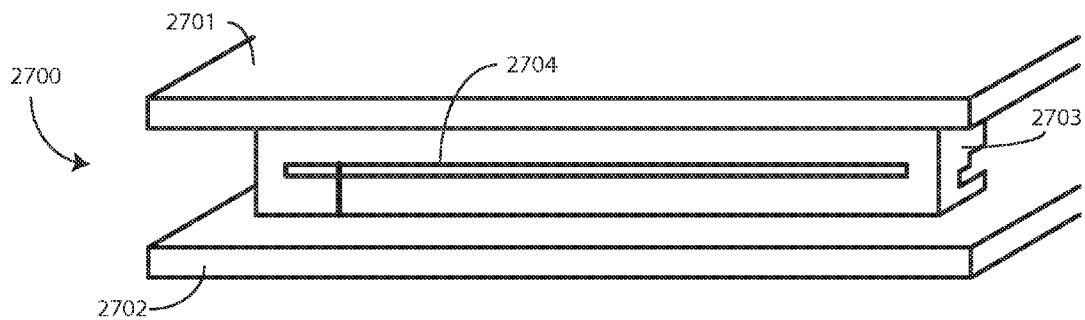
**FIG. 24**



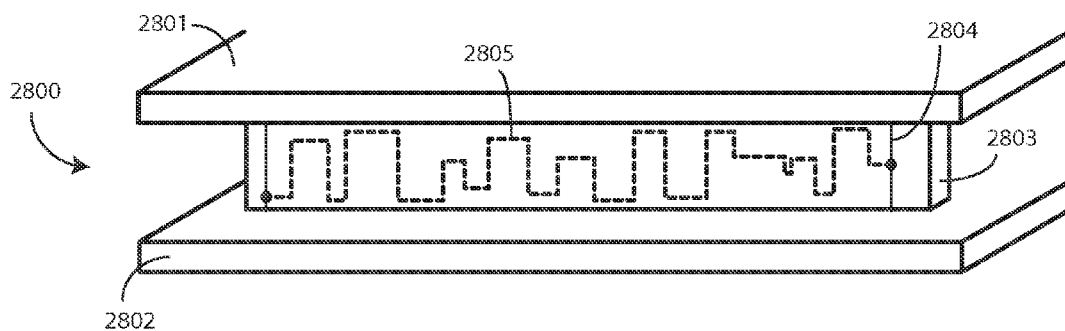
**FIG. 25**



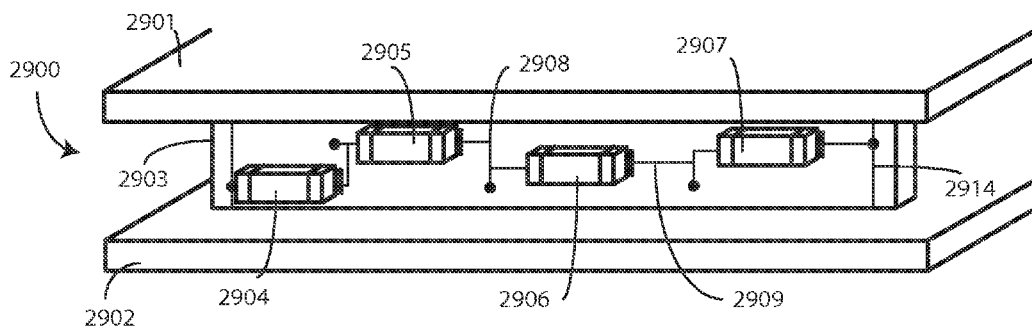
**FIG. 26**



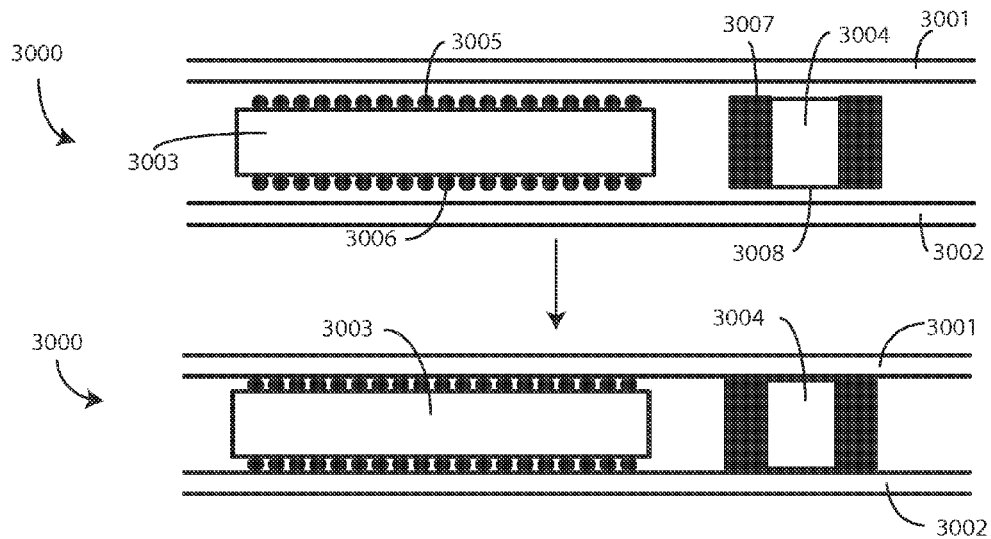
**FIG. 27**



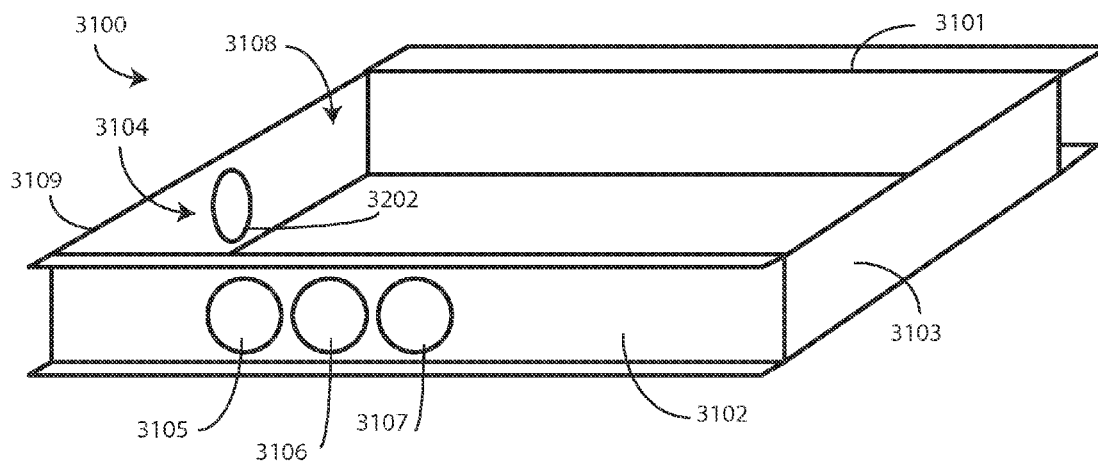
**FIG. 28**



**FIG. 29**

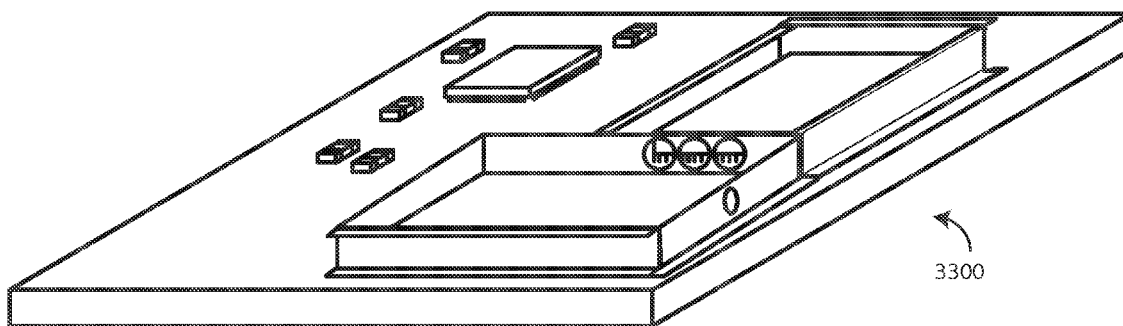
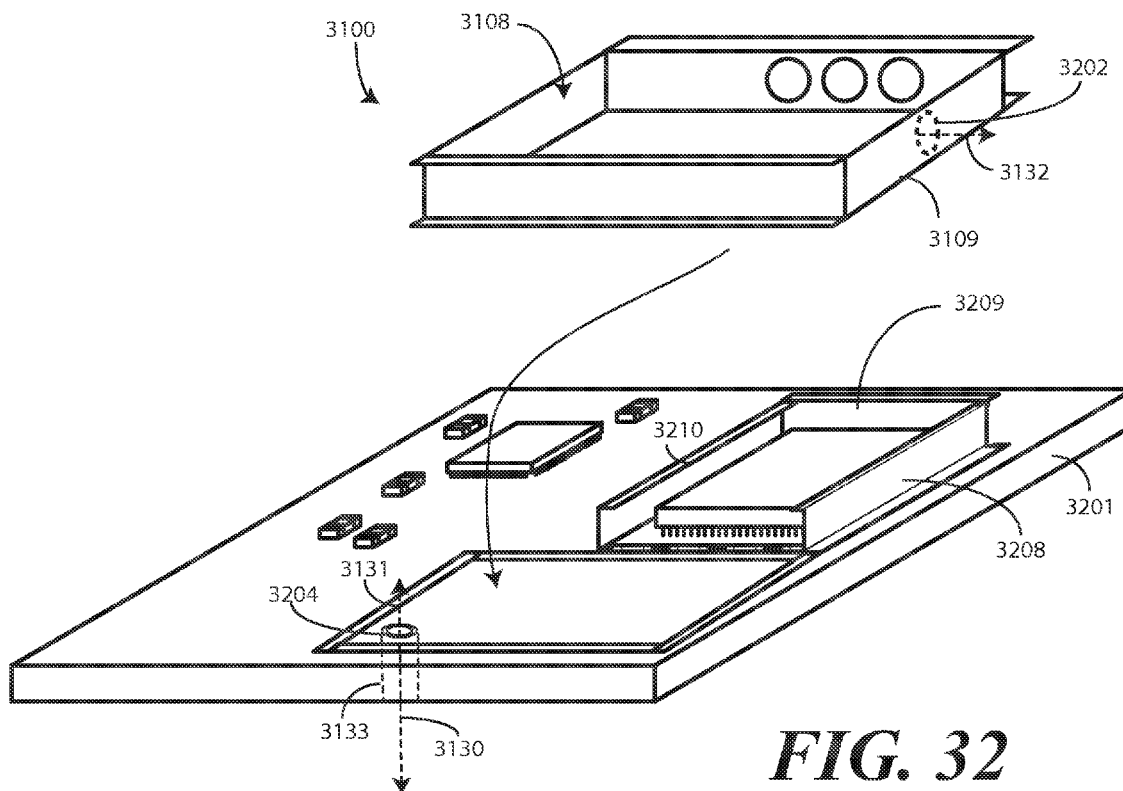


**FIG. 30**



**FIG. 31**





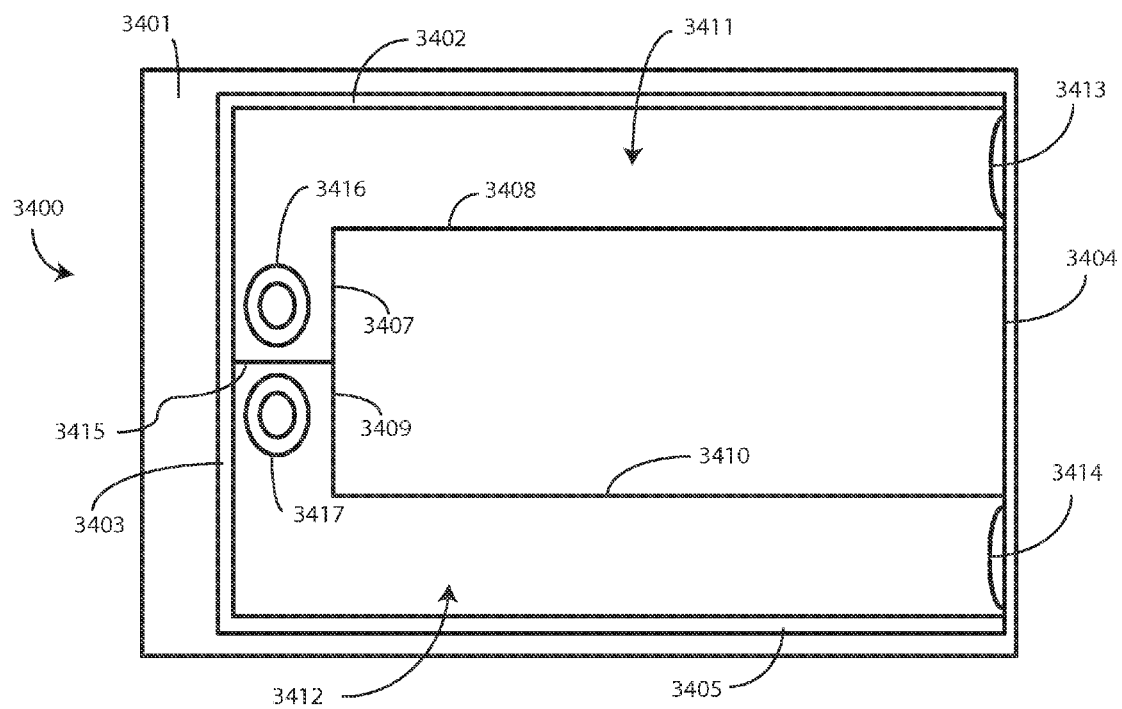
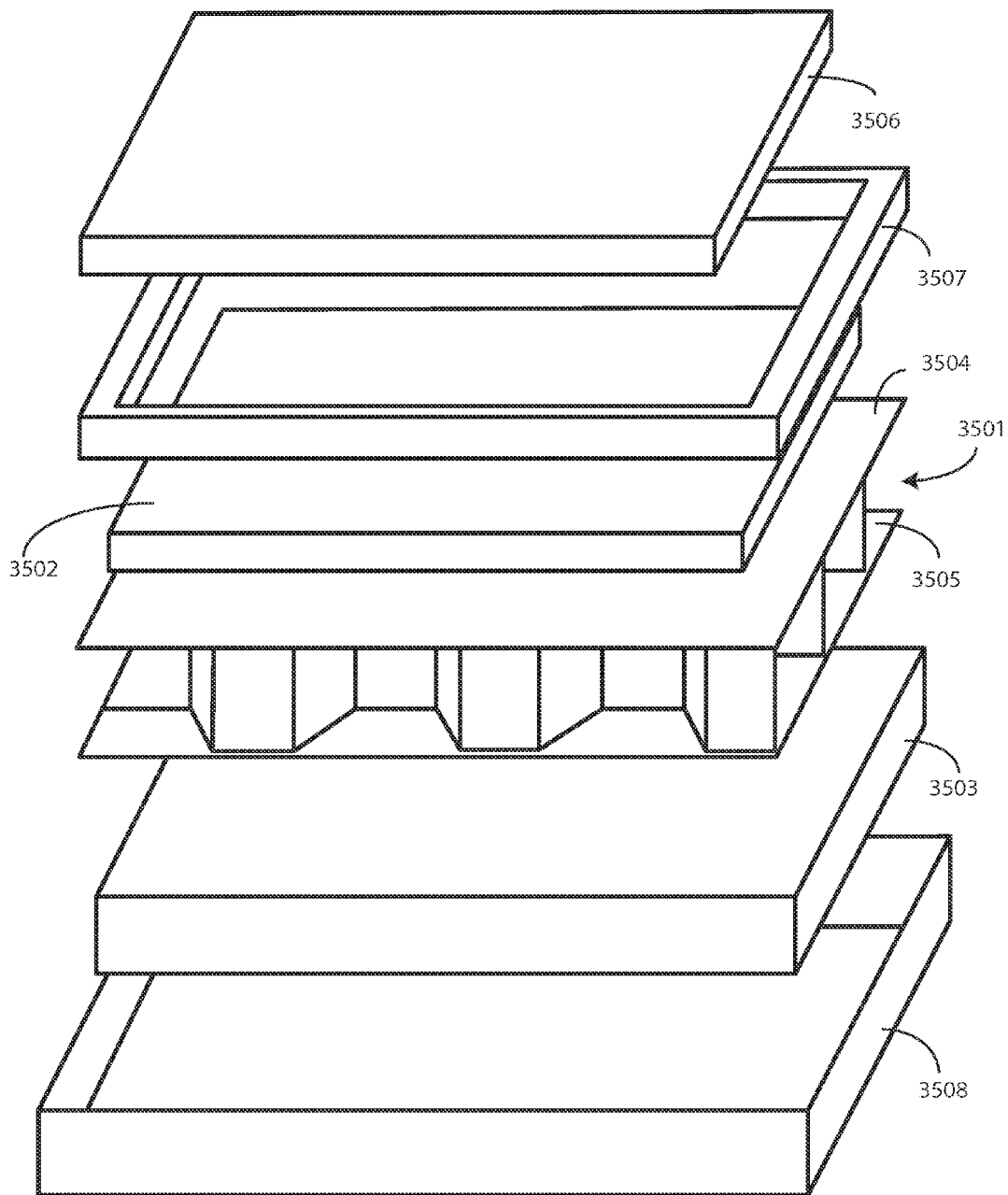
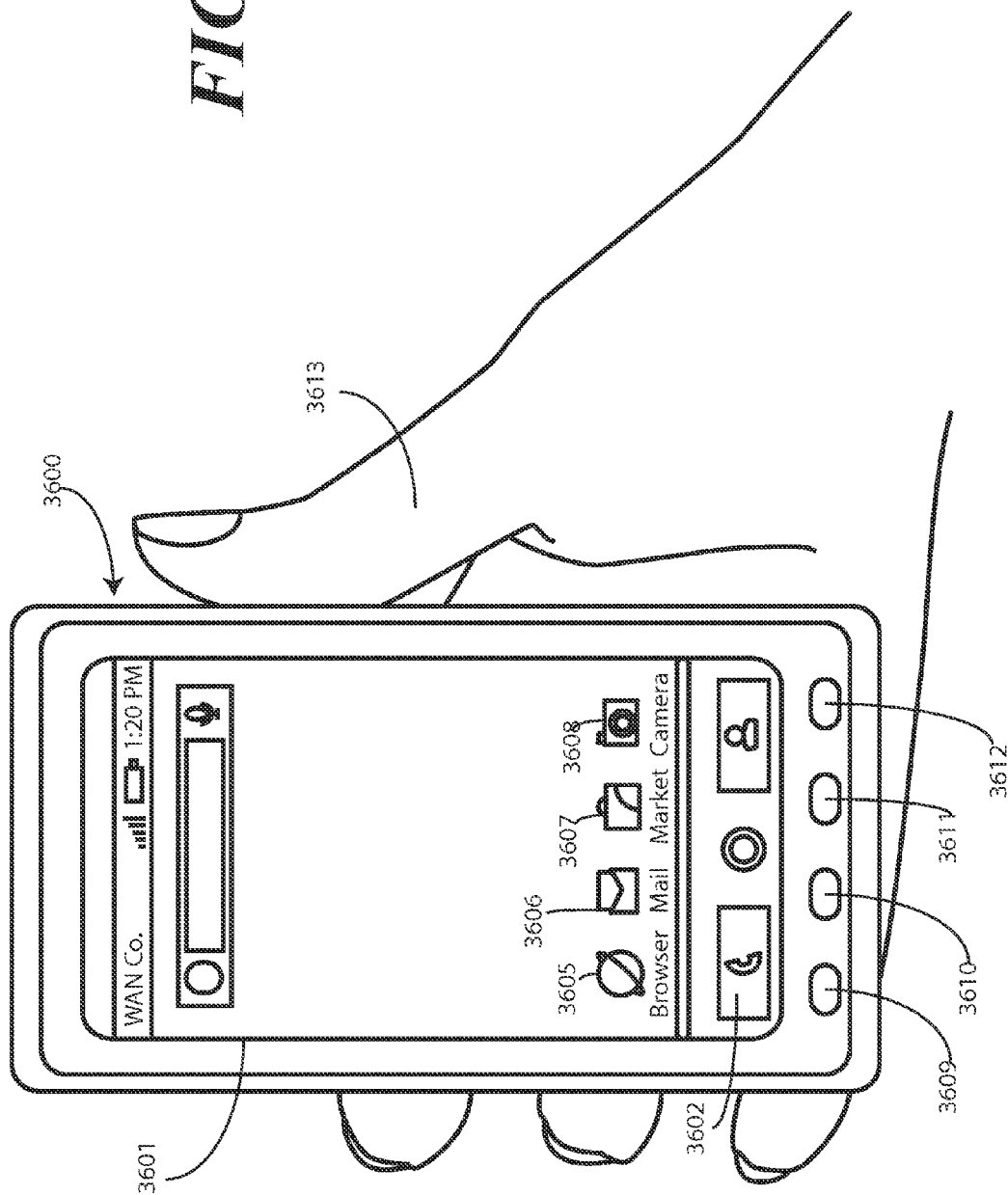


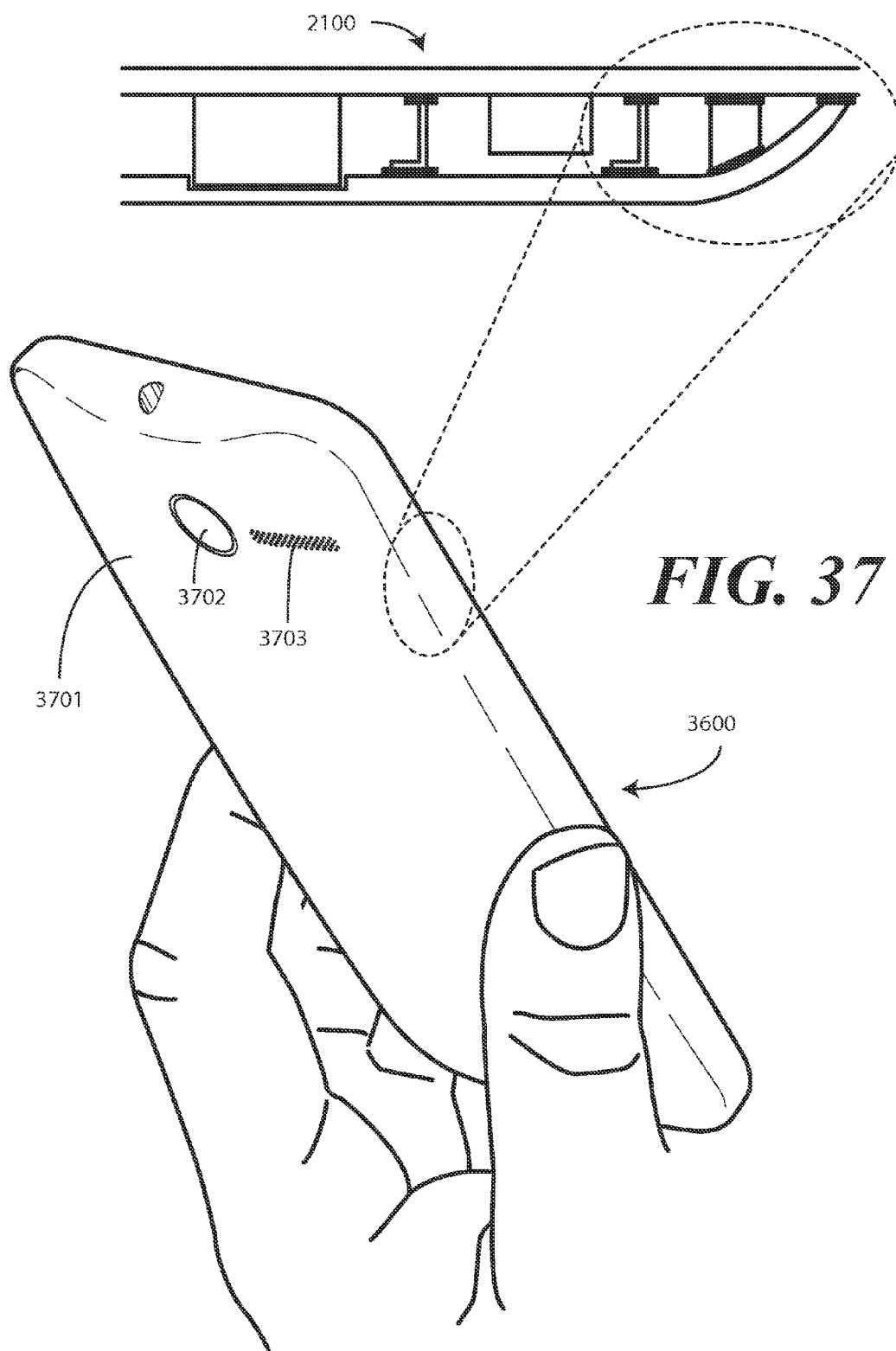
FIG. 34

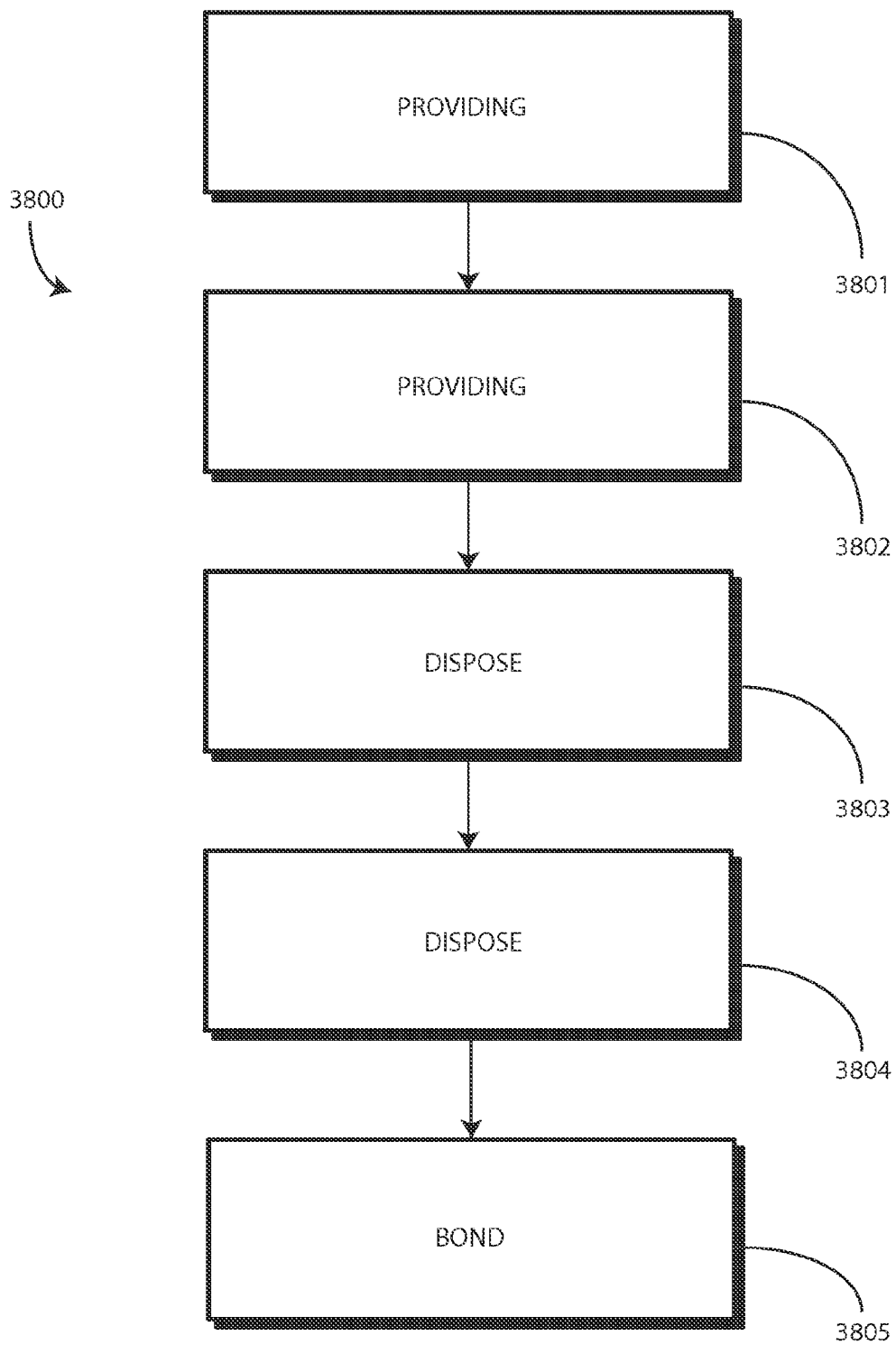


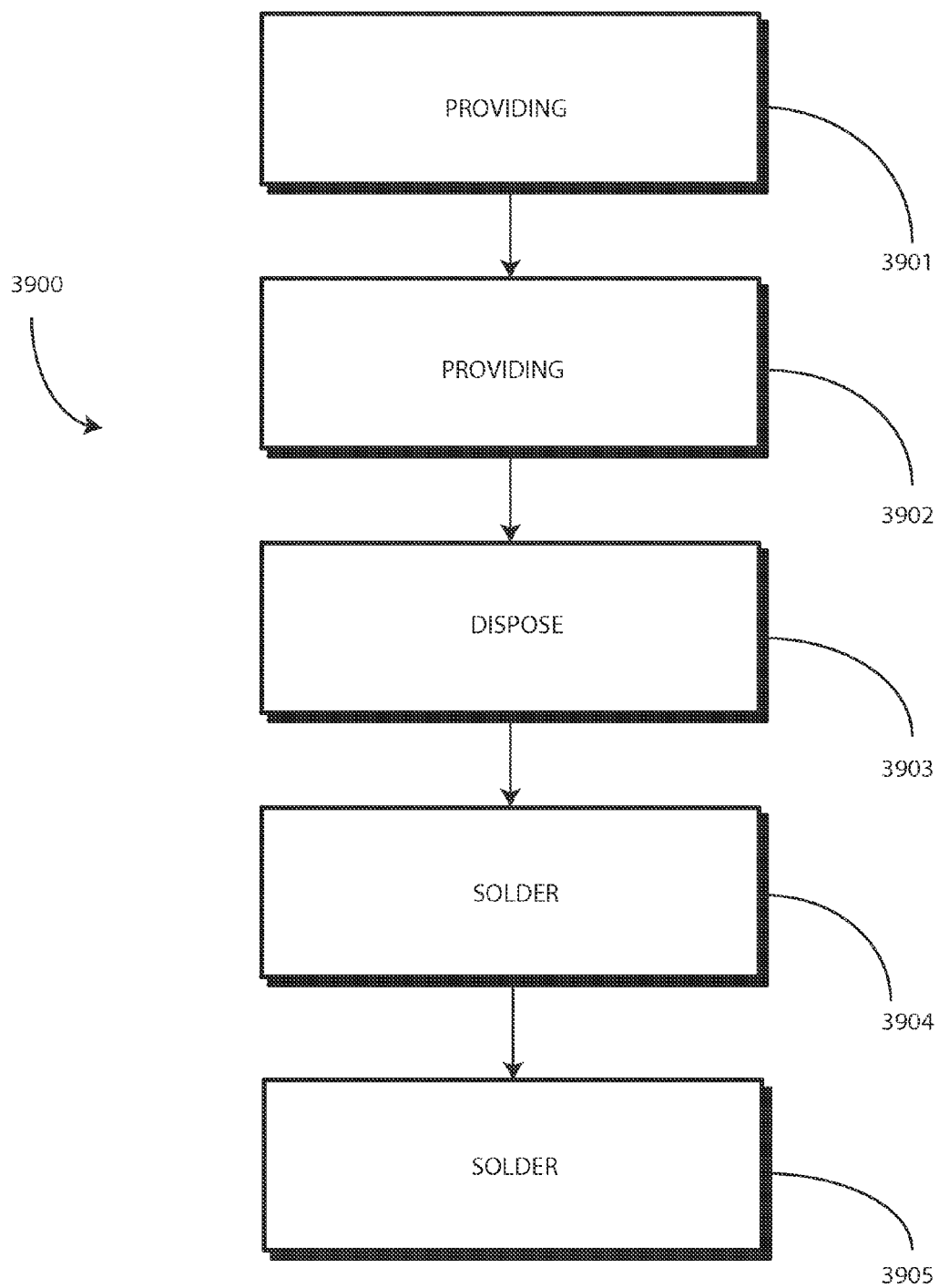
**FIG. 35**

FIG. 36

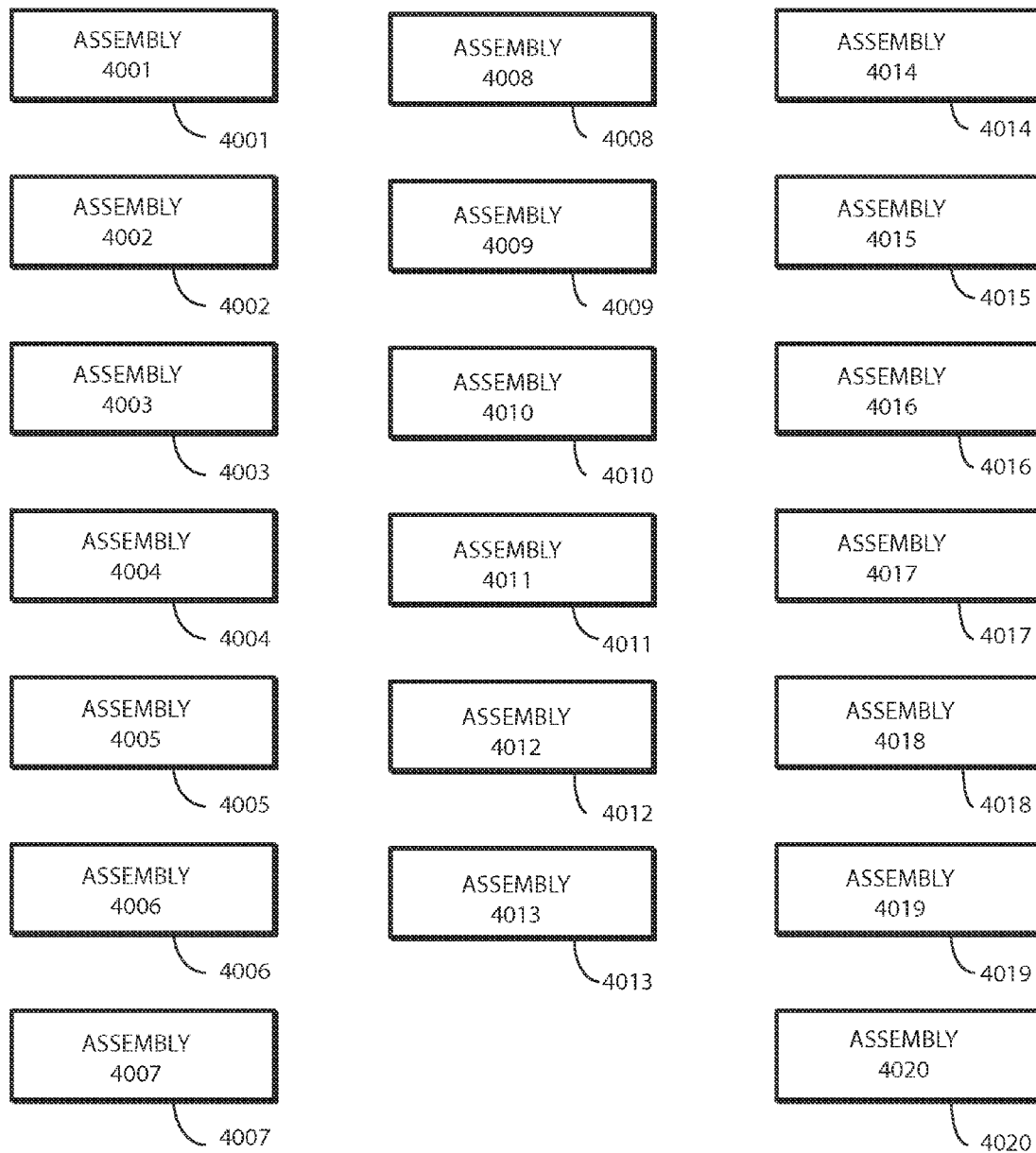




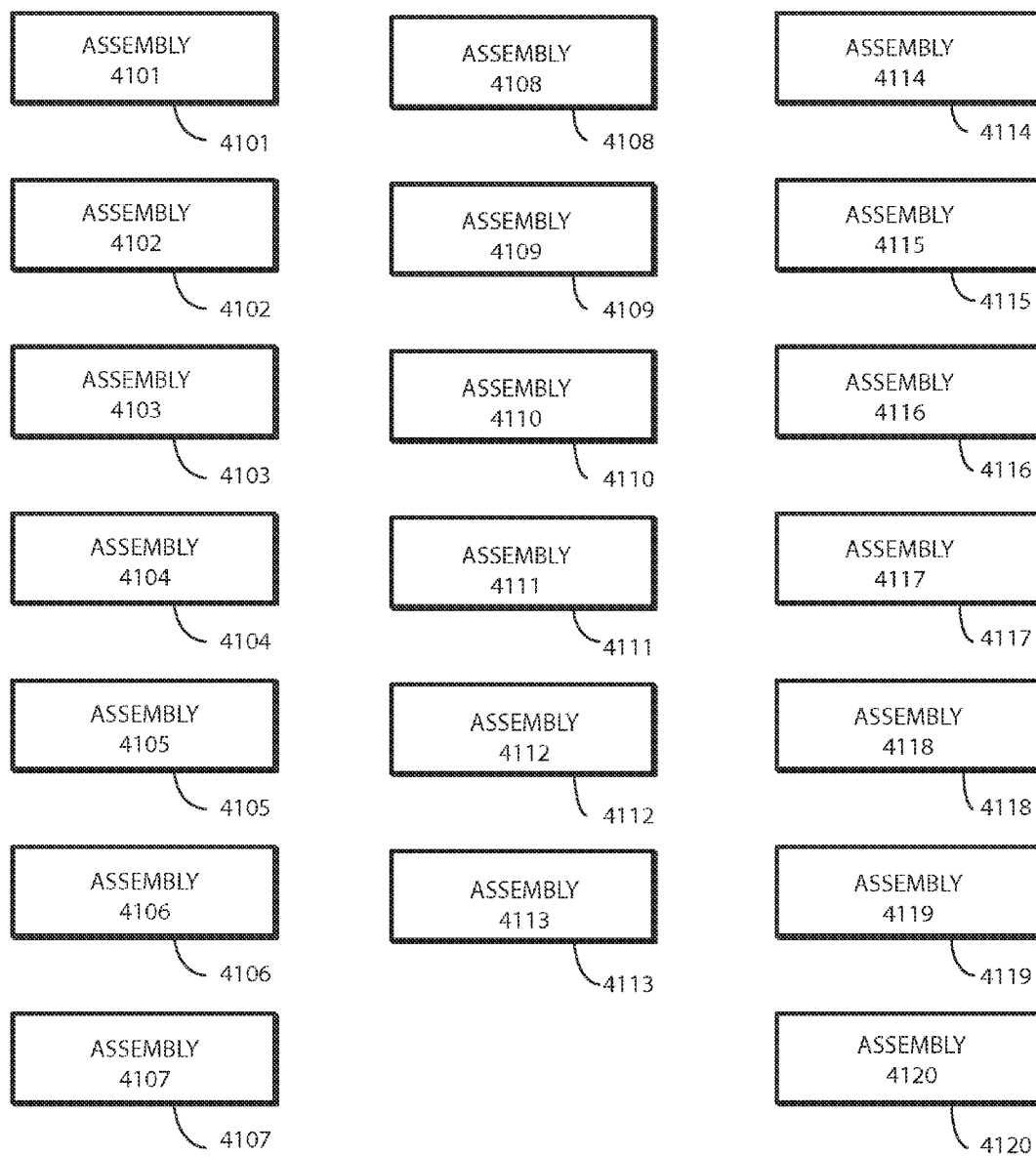
***FIG. 38***



**FIG. 39**

**FIG. 40**



**FIG. 41**

1

# CIRCUIT ASSEMBLY AND CORRESPONDING METHODS

## BACKGROUND

### 1. Technical Field

This disclosure relates generally to a circuit assembly, and more particularly to a circuit assembly for electronic devices.

### 2. Background Art

“Intelligent” portable electronic devices, such as smart phones, tablet computers, and the like, are becoming increasingly powerful computational tools. Moreover, these devices are becoming more prevalent in today’s society. For example, not too long ago a mobile telephone was a simplistic device with a twelve-key keypad that only made telephone calls. Today, “smart” phones, tablet computers, personal digital assistants, and other portable electronic devices not only make telephone calls, but also manage address books, maintain calendars, play music and videos, display pictures, and surf the web.

As the capabilities of these electronic devices have progressed, so too have their user interfaces. Keypads having a fixed number of keys have given way to sophisticated user input devices such as touch sensitive screens or touch sensitive pads. Touch sensitive displays include sensors for detecting the presence of an object such as a finger or stylus. By placing the object on the touch sensitive surface, the user can manipulate and control the electronic device without the need for a physical keypad.

One drawback to the increasingly sophisticated technologies on modern electronic devices is that they are increasingly prone to damage. If a display or other component becomes damaged, perhaps due to drop impact, the device can be rendered unusable. It would be advantageous to have an improved electronic device with increased structural stability without compromising size or performance measurements.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a prior art shield.

FIG. 2 illustrates a sectional, elevation view of a prior art shield.

FIG. 3 illustrates an exploded view of a prior art device.

FIG. 4 illustrates a prior art device.

FIG. 5 illustrates a perspective view of one explanatory substrate bridging member in accordance with one or more embodiments of the disclosure.

FIG. 6 illustrates a side elevation view of one explanatory substrate bridging member in accordance with one or more embodiments of the disclosure.

FIG. 7 illustrates a front elevation view of one explanatory substrate bridging member in accordance with one or more embodiments of the disclosure.

FIG. 8 illustrates a top plan view of one explanatory substrate bridging member in accordance with one or more embodiments of the disclosure.

FIG. 9 illustrates a perspective view of an alternate substrate bridging member in accordance with one or more embodiments of the disclosure.

FIG. 10 illustrates a perspective view of another alternate substrate bridging member in accordance with one or more embodiments of the disclosure.

FIG. 11 illustrates a substrate bridging member configured in accordance with one or more embodiments of the disclosure in illustrative packaging.

2

FIG. 12 illustrates an explanatory circuit substrate configured in accordance with one or more embodiments of the disclosure.

FIG. 13 illustrates explanatory substrate bridging members being applied to an explanatory substrate in accordance with one or more methods of the disclosure.

FIG. 14 illustrates an explanatory circuit substrate configured in accordance with one or more embodiments of the disclosure.

FIG. 15 illustrates an explanatory circuit substrate configured in accordance with one or more embodiments of the disclosure.

FIG. 16 illustrates an explanatory solder pad and resistive element assembly in accordance with one or more embodiments of the disclosure.

FIG. 17 illustrates one or more assembly methods for a circuit assembly in accordance with one or more embodiments of the disclosure.

FIG. 18 illustrates an explanatory circuit assembly in accordance with one or more embodiments of the disclosure.

FIG. 19 illustrates an alternate circuit assembly in accordance with one or more embodiments of the disclosure.

FIG. 20 illustrates a sectional view of one explanatory circuit assembly in accordance with one or more embodiments of the disclosure.

FIG. 21 illustrates a sectional view of a circuit assembly in accordance with one or more embodiments of the disclosure.

FIG. 22 illustrates a sectional view of another circuit assembly in accordance with one or more embodiments of the disclosure.

FIG. 23 illustrates a sectional view of another circuit assembly in accordance with one or more embodiments of the disclosure.

FIG. 24 illustrates a sectional view of another circuit assembly in accordance with one or more embodiments of the disclosure.

FIGS. 25-26 illustrate a sectional view of another circuit assembly in accordance with one or more embodiments of the disclosure.

FIG. 27 illustrates a sectional view of another circuit assembly in accordance with one or more embodiments of the disclosure.

FIG. 28 illustrates a sectional view of another circuit assembly in accordance with one or more embodiments of the disclosure.

FIG. 29 illustrates a sectional view of another circuit assembly in accordance with one or more embodiments of the disclosure.

FIG. 30 illustrates a sectional view of another circuit assembly in accordance with one or more embodiments of the disclosure.

FIG. 31 illustrates a sectional view of another circuit assembly in accordance with one or more embodiments of the disclosure.

FIG. 32 illustrates explanatory substrate bridging members being applied to an explanatory substrate in accordance with one or more methods of the disclosure.

FIG. 33 illustrates an explanatory circuit substrate in accordance with one or more embodiments of the disclosure.

FIG. 34 illustrates an explanatory circuit substrate in accordance with one or more embodiments of the disclosure.

FIG. 35 illustrates an exploded view of one explanatory electronic device in accordance with one or more embodiments of the disclosure.

FIG. 36 illustrates one explanatory electronic device in accordance with one or more embodiments of the disclosure.

FIG. 37 illustrates another explanatory electronic device in accordance with one or more embodiments of the disclosure.

FIG. 38 illustrates an explanatory method in accordance with one or more embodiments of the disclosure.

FIG. 39 illustrates another explanatory method in accordance with one or more embodiments of the disclosure.

FIG. 40 illustrates various embodiments of the disclosure.

FIG. 41 illustrates various embodiments of the disclosure.

Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions of some of the elements in the figures may be exaggerated relative to other elements to help to improve understanding of embodiments of the present disclosure.

#### DETAILED DESCRIPTION OF THE DRAWINGS

Embodiments of the disclosure are now described in detail. Referring to the drawings, like numbers indicate like parts throughout the views. As used in the description herein and throughout the claims, the following terms take the meanings explicitly associated herein, unless the context clearly dictates otherwise: the meaning of “a,” “an,” and “the” includes plural reference, the meaning of “in” includes “in” and “on.” Relational terms such as first and second, top and bottom, and the like may be used solely to distinguish one entity or action from another entity or action without necessarily requiring or implying any actual such relationship or order between such entities or actions. Also, reference designators shown herein in parenthesis indicate components shown in a figure other than the one in discussion. For example, talking about a device (10) while discussing figure A would refer to an element, 10, shown in figure other than figure A.

As electronic devices become smaller and thinner, their components can become more fragile. A large, blocky device can provide padding and mechanical support for the external components when the device is dropped for example. When housing members and other mechanical structures become thinner, items that once provided mechanical strength can become flexible and prone to damage from external forces. Embodiments of the disclosure contemplate that there is a need in thin devices to increase the mechanical strength of the overall device. At the same time, this increase in structural stability must be accomplished without causing the device to get thicker and without sacrificing electrical and system performance.

Embodiments of the disclosure revolutionize conventional circuit assemblies by bonding substrate bridging members between two circuit substrates. Where the substrate bridging members are metal, or have metal coated or disposed thereon, they can be arranged to provide both mechanical and electromagnetic functions within a circuit assembly. For example, the substrate bridging members can be disposed about an electromagnetically sensitive component to shield the component from electromagnetic energy. At the same time, by bonding the substrate bridging members between two substantially parallel circuit substrates, a “honeycomb” structure is created that provides increase mechanical support and stability to the circuit assembly. Accordingly, mechanical strength can be increased from within the circuit substrate. This is in contrast to prior art designs where mechanical strength is applied to a circuit substrate by a mechanical housing or exoskeleton. Embodiments of the disclosure provide very robust and mechanically sound circuit assemblies, and thus robust and mechanically sound electronic devices, without the need for increasing the mechanical features of the housing or exterior framing materials. As will be shown

below, in one or more embodiments, a robust electronic device can be created using a minimal housing that is simply snapped about the circuit assembly. The robustness of this assembly is derived by the increased mechanical strength of the interior circuit assembly.

In one embodiment, a circuit assembly comprises a first circuit substrate and a second circuit substrate. In one embodiment, the circuit substrates are fiberglass or FR4 printed circuit boards defining major faces on each side. FR4 is a grade designation assigned to glass-reinforced epoxy laminate sheets. For example, the first circuit substrate can define a first major face, while the second circuit substrate defines a second major face, and so forth.

A plurality of electrical components can be disposed on one or more of the major faces. For example, in one embodiment a plurality of electrical components is disposed on the first major face of the first circuit substrate. In another embodiment, a plurality of electrical components is disposed on two sides of the first circuit substrate. In another embodiment, a plurality of electrical components is disposed on one or both sides of the second circuit substrate. Of course, combinations of these embodiments can be used as well.

One or more substrate bridging members is then bonded between the two substrates. In one embodiment, the one or more substrate bridging members are soldered to the first circuit substrate such that they extend substantially perpendicularly from a major face of the first circuit substrate. The second circuit substrate can then be oriented substantially parallel with the first circuit substrate so that the other end of one or more of the substrate bridging members can be bonded to one of its major faces. In one embodiment, the second bonding comprises soldering that occurs when current is applied to a solder pad and resistive element assembly. This results in each substrate bridging member defining a unitary structure having a first end bonded to the first major face and a second end bonded to the second major face to bridge the first circuit substrate and the second circuit substrate. This “double-board” assembly creates a “honeycomb” effect between the two circuit substrates and greatly increases bend strength and resistance to twisting, especially where the substrate bridging members are disposed along the two circuit substrates with sufficient density. Circuit assemblies configured in accordance with embodiments of the disclosure can remove the need for an exoskeleton and screws when used in electronic devices. In short, one or more embodiments of the disclosure provide a structurally strong method of stacking circuit boards or substrates so that that device housing elements are no longer needed to provide “structure” or mechanical rigidity to the device.

Prior to explaining embodiments of the disclosure, a discussion of prior art electronic devices is in order. Turning to FIG. 1, illustrated therein is a prior art shield 100. As shown, the prior art shield 100 has a planar top surface 101 and planar sidewalls 102, 103, 104 extending orthogonally from each edge of the planar top surface 101. This particular prior art shield 100 includes flanges 105, 106, 106 so that the prior art shield 100 can be soldered to a circuit board.

Turning to FIG. 2, illustrated therein is the prior art shield 100 coupled to a printed circuit board 200. The planar top surface 101 covers several electrical components 201, 202, 203, 204.

Turning to FIG. 3, the circuit board 200 is being subjected to mechanical loading. This loading is typical of loading the circuit board 200 may experience in a thin electronic device when the device is dropped or otherwise subjected to mechanical forces. As shown at point 301, this causes the circuit board 200 to flex. This occurs because the thin device

5

may not have sufficient mechanical support to adequately provide resistance to the mechanical forces.

The prior art shield **100**, being manufactured from a thick metal, remains rigid. Accordingly, the assembly **300** functions like an inverted trampoline, with the prior art shield **100** serving as the trampoline frame, and the circuit board **200** serving as the trampoline mat. Each of the electrical components **201, 202, 203, 204** translates vertically toward the planar top surface **101** of the prior art shield **100**, thereby causing electrical connections to be broken at points **302, 303, 304, 305, 306**. This “trampoline effect” renders the assembly **300** non-functional.

Embodiments of the present disclosure serve to prevent the trampoline effect—as well as other mechanical distortions of a circuit assembly and/or components attached thereto—by providing substrate bridging members disposed interior to two layered circuit substrates. This results in a shield with increased mechanical structure and with features that limit the vertical translation that a substrate—or components coupled thereto—can make, thereby reducing or preventing damage. In one embodiment, a circuit assembly comprises a first substrate defining a first side of the circuit assembly and a second substrate defining a second side of the circuit assembly. One or more substrate bridging members are then disposed interior to the circuit assembly. Each substrate bridging member has a unitary structure with a first end soldered or otherwise bonded to the first substrate and a second end soldered or otherwise bonded to the second substrate.

Embodiments of the disclosure have several advantages over prior art designs. To begin, the honeycomb structure defined by the substrate bridging members provides resistance to the trampoline effect by increasing the assembly’s resistance to bending. Second, the honeycomb structure improves the bending moment and reduces twisting of the assembly. Third, the honeycomb structure increases the available major face area of each circuit substrate along which electronic components can be placed compared to prior art designs.

To better understand some of the advantages offered by embodiments of the disclosure, it is well to understand how prior art electronic devices are traditionally made. Turning now to FIG. 4, illustrated therein is a prior art electronic device **400**.

A first housing member **403** is shown above a fascia layer **402**. The first housing member **403** defines an aperture **401**. The fascia layer **402** fits within the first housing member **403** to span and cover the aperture **401**. Some designers refer to the fascia layer **402** as a “lens,” although the fascia layer **402** generally does not include optical magnification properties.

A display assembly **405** is disposed beneath the fascia layer **402**. The illustrative display assembly **405** of FIG. 4 includes two substrate layers **406, 407** sealed together at a seam **408** disposed along a periphery of each substrate layer **406, 407**. As used herein, “periphery” refers to an outer region of an area or object, or in this case, an outer region disposed just within a perimeter **409** of the substrate layers **406, 407**.

A circuit board **410** having the shield **100** of FIG. 1 coupled thereto is then disposed beneath the display assembly **405**. A second housing member **411** can then be coupled to the first housing member **403** to provide mechanical support to the display assembly **405**, circuit board **410**, and other electronic components.

While the prior art design can work well in practice, when one desires a very thin device, problems can arise. Illustrating by example, in one embodiment the display assembly **405** comprises two substrate layers **406, 407** having a liquid crystal or organic polymer disposed therebetween. In the case of

6

an organic light emitting diode layer, a film of organic material will be disposed between the two substrate layers **406, 407**. Each substrate layer **406, 407** is coupled to the other by the seam **408**. The seam **408** can be formed by fusing the two substrate layers **406, 407** together with a fused weld known as a “frit.” A frit is a ceramic composition that is thermally fused between layers of glass to form a seam or seal between those two substrates. Experimental testing has shown the frit forming the seam is very brittle. Moreover, testing has shown that the frit forming the seam fractures easily allowing the glass substrates to separate in a cleavage mode. When this occurs, the organic film sealed between the glass substrates and the frit then leaks out, rendering the display inoperable. Unless the first housing member **403** and the second housing member **411** are sufficiently thick as to provide sufficient mechanical support, dropping the prior art electronic device **400** can cause the frit to break, thereby rendering the prior art electronic device **400** unusable. This thickness and mechanical support requirement limits how thin the prior art electronic device **400** can ultimately become.

A second problem involves the trampoline phenomenon discussed above with reference to FIG. 3. Unless the first housing member **403** and the second housing member **411** are sufficiently thick as to provide sufficient mechanical support, dropping the prior art electronic device **400** can cause electronic components to break from the circuit board **410** due to the trampoline effect. Such breakage can render the prior art electronic device **400** unusable. This thickness and mechanical support requirement further limits how thin the prior art electronic device **400** can ultimately become.

Other problems with the prior art electronic device **400** involve cost and manufacturing issues. In many embodiments, the prior art electronic device will include a metal frame **412** that is manufactured from a metal such as zinc or magnesium. The metal frame **412** is generally not a shield. Sometimes the metal frame **412** takes the shape of a “figure eight,” sometimes it is disposed just on the exterior of the circuit board **410** shown in FIG. 4, and sometimes it has two sections running through it instead of one. In any event, the function of the metal frame **412** is to reside about the perimeter of the circuit board **410** and to hold the circuit board **410** in place.

The circuit board **410** physically mounts to the metal frame **412**, and the metal frame **412** physically mounts to either the first housing member **403** or the second housing member **411**. Foam or other supporting materials are then stuffed beneath the display assembly **405** and the first housing member **403** is attached to the second housing member **411** with several screws (not shown) that may pass through or into the metal frame **412**.

The problem with this design is twofold: First, where the first housing member **403** and second housing member **411** are plastic, the stiffest element in the prior art electronic device **400** is the display assembly **405**. Since the shield **100** spans only a portion of the circuit board **410**, it can form a fulcrum under the display assembly **405**. Accordingly, the device needing the most protection, i.e., the display assembly **405**, is the stiffest element and is sitting on a fulcrum attached to a circuit board **410** that can trampoline when exposed to external mechanical forces. When the prior art electronic device **400** is dropped and the housing members are too thin, damage occurs. Moreover, as the housing members get thinner and thinner, it becomes more and more difficult to protect the display assembly **405**.

The second problem is cost. The metal frame **412** is quite expensive. The screws are cumbersome and costly to install and to remove for reworking purposes. Some assemblies

7

require solder balls to be added to the intersection of the shield **100** and circuit board **410** in an attempt to add rigidity to the circuit board **410** as well. When the circuit board **410** is reworked in service, heating of the shield(s) (there can be more than one) is required twice—once to remove the shield(s) and once to replace the shield(s). Such heating can cause electrical components on the circuit board **410** to become dislodged, thereby requiring an additional reflow or hand soldering operation. All of these issues combine to make the prior art electronic device **400** very costly.

Embodiments of the present disclosure advantageously work to prevent cleavage and other failure modes, and also to reduce cost, by providing a circuit assembly comprising a first substrate defining a first side of the circuit assembly and a second substrate defining a second side of the circuit assembly. At least one electrical component is disposed on at least one of the first substrate or the second substrate interior to the circuit assembly. One or more unitary shield elements disposed interior to the circuit assembly and having a first end soldered to the first substrate and a second end soldered to the second substrate. This will be explained in more detail below.

Turning now to FIGS. 5-8, illustrated therein are views of one explanatory substrate bridging member **500** configured in accordance with one or more embodiments of the disclosure. The embodiment of FIGS. 5-8 is one of the simpler bridging member configurations. Other more complex ones will be shown with reference to FIGS. 9 and 10 below. Of course, each of these embodiments is explanatory only, as numerous other bridging member configurations will be obvious to those of ordinary skill in the art having the benefit of this disclosure.

FIG. 5 illustrates a perspective view of the substrate bridging member **500**, while FIG. 6 illustrates a side elevation view thereof. FIG. 7 illustrates a front elevation view of the substrate bridging member **500**, while FIG. 8 illustrates a top plan view thereof.

The substrate bridging member **500** can be made from a variety of materials. In one embodiment, the substrate bridging member **500** is manufactured from metal. Metal is a suitable material for the substrate bridging member **500** for multiple reasons. First, when the substrate bridging member **500** is made from metal, multiple substrate bridging members can be placed about the perimeter of one or more electrical components to electromagnetically shield the one or more electrical components. Second, in one or more embodiments the substrate bridging member **500** is soldered to a pair of circuit substrates. Manufacturing the substrate bridging member **500** from metal facilitates soldering or plating for soldering processes.

In one embodiment, the substrate bridging member **500** is made from a bendable metal that is easily formable and works well in plating processes. Plating can be advantageous when the substrate bridging member **500** is used in soldering operations. In one or more embodiments, the substrate bridging member **500** is a soft, malleable metal that works well in forming processes. In one embodiment, the thickness of the substrate bridging member **500** is about 0.15 millimeters to 0.2 millimeters. However, it should be noted that the thickness of the substrate bridging member **500** could vary is, for example, one identified an area along the substrate bridging member **500** requiring increased stiffness.

In one embodiment, the substrate bridging member **500** can be manufactured from a sheet metal frame. In another embodiment, the substrate bridging member **500** can be machine formed from cold rolled steel. In other embodiments, the substrate bridging member **500** can be manufactured from cast metal. Other materials and methods of manu-

8

facture for the shield will be obvious to those of ordinary skill in the art having the benefit of this disclosure. Illustrating by example, the substrate bridging member **500** could be manufactured from a material other than metal, but plated with tin or other materials to facilitate soldering to one or more circuit substrates. In yet other embodiments, the substrate bridging member **500** could be manufactured from other materials, such as plastic, that then may be bonded to substrates with adhesives or other techniques.

In one or more embodiments, the substrate bridging member **500** defines a unitary structure having a first end **501**, a bridge wall **503**, and a second end **502**. As used herein, “unitary” is used to mean a single or uniform entity that includes a single piece of material. Accordingly, the substrate bridging member **500** of FIGS. 5-8 is “unitary” in that a singular piece of metal is used to create the first end **501**, the second end **502**, and the bridge wall **503**.

In one or more embodiments, the first end **501** can simply be the base of the bridge wall **503**. Said differently, while the first end **501** extends substantially orthogonally from the bridge wall **503** in the explanatory embodiment of FIG. 5, the bottom edge **550** of the bridge wall **503** could define the first end **501** in other embodiments, examples of which will be shown below with reference to FIGS. 20-21. Also, while the first end **501** and second end **502** are shown as being substantially parallel in FIG. 5, they may be skew or non-parallel as shown in FIG. 22 below. Other configurations will be obvious to those of ordinary skill in the art having the benefit of this disclosure.

As will be described with reference to FIGS. 12-17 below, where manufactured from metal, the explanatory substrate bridging member **500** can be used to shield integrated circuits or other electronic components from electromagnetic emissions. The first end **501** of one or more substrate bridging members **500** can be soldered or otherwise coupled to a circuit substrate so as to extend distally from the circuit substrate along a perimeter of at least one of a plurality of electronic components. In one or more embodiments, the one or more substrate bridging members **500** extend substantially orthogonally from the circuit substrate such that their bridge walls **503** form a wall about the perimeter of the electronic components. A second substrate can then be soldered or otherwise coupled to the second end **502** of the one or more substrate bridging members **500**. Where one or more of the first circuit substrate or the second circuit substrate comprising a ground plane interior to the perimeter defined by the one or more substrate bridging members **500**, the ground plane can form the “top” of a “shield” defined by the one or more substrate bridging members **500** and the ground plane.

Where used as a shield, the substrate bridging members are suitable for use in many different types of electronic devices. Illustrating by example, the substrate bridging members **500** can be used in mobile communication devices, such as smartphones, tablet computers, and so forth. Those of ordinary skill in the art having the benefit of this disclosure will understand that mobile communication devices are merely one type of electronic device for which the substrate bridging members **500** are suited, and are being used purely for illustrative purposes. Shields configured in accordance with one or more embodiments of the disclosure are certainly usable and compatible with any number of different structures and devices.

Turning to FIG. 9, illustrated therein is another explanatory substrate bridging member **900**. Like the substrate bridging member (**500**) of FIGS. 5-8, the substrate bridging member **900** of FIG. 9 defines a unitary structure having a first end **901**, a bridge wall **903**, and a second end **902**. However, the substrate bridging member **900** of FIG. 9 differs from that of FIG.

5 in several ways. First, even though the substrate bridging member **900** is still unitary, the first end **901** and the second end **902** are segmented and include disconnected segments. Second, the bridge wall **903** is non-linear due to a bend **904** located interior to the bridge wall's edges.

By applying different bends to various portions of the substrate bridging member **900**, any number of segments of the first end **901** and the second end **902** can be formed. Additionally, the bridge wall **903** can take a variety of shapes. This is shown illustratively in FIG. **10**, where the first end **1001** and the second end **1002** of the substrate bridging member **1000** are multi-segmented due to multiple bends **1004** occurring in the bridge wall **1003**. The shapes and structures of the substrate bridging members of FIGS. **5-10** are illustrative only. Others will be obvious to those of ordinary skill in the art having the benefit of the disclosure.

In the illustrative embodiments of FIGS. **5-10**, the first end and second end of each substrate bridging member extends substantially orthogonally from its respective bridge wall. Using the substrate bridging member **500** of FIG. **5** as an example, the first end **501** extends substantially orthogonally from the bridge wall **503**. Similarly, the second end **502** extends substantially orthogonally from the bridge wall **503**. This configuration is advantageous for a couple of reasons. First, the orthogonal first and second ends assist in the substrate bridging member **500** being able to "stand up" on a circuit substrate prior to soldering or other coupling operations. For example, if the substrate bridging member **500** is placed such that the first end **501** is in solder paste disposed on a major face of a substrate prior to a reflow operation, the orthogonal nature of the first end **501** provides additional surface area to contact with the solder paste. Second, the orthogonal nature of the first end **501** and the second end **502** makes mechanical assembly via pick and place operations simpler.

While orthogonal ends are one illustrative embodiment, others will be obvious to those of ordinary skill in the art having the benefit of this disclosure. For example, in some embodiments, the first end **501** and second end **502** will not extend outwardly at all from the bottom edge of the bridge wall **503**. In other embodiments, each of the first end **501** and the second end **502** will have dimensions less than that of the bridge wall **503** such that multiple segments can extend from the bottom edge of the bridge wall **503**. Said differently, multiple "feet" can form the first end **501** or the second end **502**, rather than the single "foot" shown in FIG. **5**.

In one or more embodiments, one or more of the first end **501** or the second end **502** will be plated to facilitate soldering. Illustrating by example, in one or more embodiments, the first end **501** and the second end **502** can be tin-plated to make soldering more reliable.

As noted above, in one or more embodiments, the substrate bridging member **500** can be placed on a circuit substrate by way of a pick and place operation. Turning now to FIG. **11**, illustrated therein is illustrative packaging suitable for use with the substrate bridging member **500** in pick and place operations. As shown in FIG. **11**, in one embodiment, the substrate bridging member **500** can be packaged and dispensed from a tape and reel package **1100**. Tape and reel provides a suitable packaging for the substrate bridging member **500** where an area of one of the first end (**501**) or the second end (**502**) is sufficient for rapid picking and placing by industrial pick and place machines. A tape and reel package **1100** can be modified to carry a plurality of substrate bridging members, regardless of shape, within each dispensing area **1101** or individual cells. The tape and reel package **1100** can include a tape **1102** carried by a reel **1103** with a number of

dispensing areas disposed along the tape **1102**. The tape **1102** can be covered by a cover strip **1104**. The substrate bridging members disposed in the tape **1102** can progress and be dispensed in a pick and place machine using a series of sprockets or holes **1105** to move the tape **1102** along as needed. In one embodiment, the substrate bridging members are packaged in the individual cells to avoid damage and/or contamination.

Turning now to FIG. **12**, illustrated therein is a first circuit substrate **1200**. In one embodiment, the first circuit substrate **1200** is a printed circuit board. In one embodiment, the first circuit substrate **1200** is manufactured from multiple layers. Some layers can be selectively placed conductive metal, such as copper or aluminum, while other layers can be insulative. In one or more embodiments, the first circuit substrate **1200** comprises a fiberglass printed circuit board. In another embodiment, the first circuit substrate **1200** is a FR4 printed circuit board.

In one embodiment, the first circuit substrate **1200** defines a first major face **1201** and a second major face **1202**. A plurality of electrical components, e.g., electrical components **1203, 1204, 1205**, can be disposed on one or more of the first major face **1201** or the second major face **1202**. In FIG. **12**, one or more electrical components are shown disposed on, and coupled to, the first major face **1201**.

In this illustrative embodiment, a plurality of solder pads **1206, 1207, 1208, 1209** define a perimeter about one of the electrical components **1204**. The electrical component **1204** disposed within the perimeter of this explanatory embodiment is an integrated circuit processor. This particular integrated circuit processor is sensitive to electromagnetic energy. Accordingly, one or more substrate bridging members are going to be used as shield walls about the perimeter. Additionally, the one or more substrate bridging members are going to provide increased mechanical strength to the circuit assembly that will ultimately be formed.

Turning now to FIG. **13**, four substrate bridging members **1301, 1302, 1303, 1304** are being placed on the solder pads **1206, 1207, 1208, 1209**. When the first circuit substrate **1200** is passed through a reflow oven, the first ends **1305, 1306, 1307, 1308** of the substrate bridging members **1301, 1302, 1303, 1304** will be bonded to the first major face **1201** of the first circuit substrate **1200** when solder paste disposed on the solder pads **1206, 1207, 1208, 1209** solders the first ends **1305, 1306, 1307, 1308** of the substrate bridging members **1301, 1302, 1303, 1304** to the solder pads **1206, 1207, 1208, 1209**. This is shown in FIG. **14**, where the first ends **1305, (1306), (1307), 1308** of the substrate bridging members **1301, 1302, 1303, 1304** have been soldered to the solder pads (**1206, 1207, 1208, 1209**) by a reflow process.

As shown in FIG. **14**, the substrate bridging members **1301, 1302, 1303, 1304** define a perimeter about the electrical component **1204**. In this illustrative embodiment, at least one substrate bridging member, e.g., substrate bridging member **1301**, is disposed interior the first circuit substrate **1200** from the electrical component **1204**. Said differently, substrate bridging member **1301** is farther toward the interior of the first major face **1201** than is the electrical component **1204**, and the electrical component **1204** is nearer the edge than is the substrate bridging member **1301**. In this illustrative embodiment, substrate bridging member **1302** is also disposed interior the first circuit substrate **1200** from the electrical component **1204**.

Turning now to FIG. **15**, illustrated therein is a second circuit substrate **1500**. As with the first circuit substrate (**1200**), in one embodiment, the second circuit substrate **1500** is a printed circuit board. In one embodiment, the second

## 11

circuit substrate **1500** is manufactured from multiple layers. Some layers can be selectively placed conductive metal, such as copper or aluminum, while other layers can be insulative. In one or more embodiments, the second circuit substrate **1500** comprises a fiberglass printed circuit board. In another embodiment, the second circuit substrate **1500** is a FR4 printed circuit board.

In one embodiment, the second circuit substrate **1500** defines a first major face (shown in FIG. **17**) and a second major face **1502**. A plurality of electrical components, e.g., electrical components **1503,1504,1505**, can be disposed on one or more of the first major face **1501** or the second major face **1502**. In the embodiment of FIG. **15**, one or more electrical components are shown disposed on, and coupled to, both the first major face (shown in FIG. **17**) and the second major face **1502**.

In this illustrative embodiment, a plurality of resistive solder assemblies **1506,1507,1508,1509** defines a perimeter. When the second circuit substrate **1500** is placed atop the first circuit substrate (**1200**), the perimeter will align with the perimeter defined by the substrate bridging members (**1301,1302,1303,1304**) about the electrical component (**1204**) such that the second ends of the substrate bridging members (**1301,1302,1303,1304**) seat against the plurality of resistive solder assemblies **1506,1507,1508,1509**. When current is passed through the plurality of resistive solder assemblies **1506,1507,1508,1509**, it will cause solder paste disposed on the plurality of resistive solder assemblies **1506,1507,1508,1509** to solder the second ends of the substrate bridging members (**1301,1302,1303,1304**) to bond to the second major face **1502** of the second circuit substrate **1500** via a resistive heat soldering process.

Turning now to FIG. **16**, illustrated therein is an explanatory embodiment of a resistive solder assembly **1600** in accordance with one or more embodiments of the disclosure. The resistive solder assembly **1600** can be attached to a major face of one or both of the first circuit substrate (**1200**) or the second circuit substrate (**1500**). In one or more embodiments, the resistive solder assembly **1600** is integral to one or both of the first circuit substrate (**1200**) or the second circuit substrate (**1500**). For example, components of the resistive solder assembly **1600** can be formed along layers of one or both of the first circuit substrate (**1200**) or the second circuit substrate (**1500**).

In one embodiment, the resistive solder assembly **1600** comprises a solder pad **1601** aligned with a resistive element **1602**. One or more electrically insulating layers **1603,1604** can be disposed between the solder pad **1601** and the resistive element **1602**. When current is applied to the resistive element **1602**, it heats, thereby melting solder paste **1605** disposed on the solder pad **1601**. When an end of a substrate bridging member abuts the solder pad **1601** and sufficient current is passed through the resistive element **1602**, the end becomes soldered to the solder pad **1601**. It should be noted that bonding methods other than soldering with resistive solder assemblies **1600** could be used. Illustrating by example, gluing substrate bridging members can be used in some embodiments as noted above. Additionally, where soldering is used, the use of resistive solder assemblies **1600** is but one technique for attaching the second substrate to the first substrate. Instead of resistive solder assemblies **1600**, one may solder by applying heat to the solder pad **1601** through a hole in the substrate, by laser welding, or by other techniques. Other bonding techniques will be obvious to those of ordinary skill in the art having the benefit of this disclosure.

In one embodiment, the resistive solder assembly **1600** heats to about 600 degrees centigrade when current is passed

## 12

through the resistive element **1602**. In one embodiment, the resistive element **1602** is not electrically coupled to the solder pad **1601**; it is instead thermally coupled to the solder pad **1601**. This can be accomplished by electrically coupling the solder pad **1601** to a ground plane and placing an electrically insulating layer **1604** between the solder pad **1601** and the resistive element **1602**. When the resistive element **1602** warms, heat is transferred to the solder pad **1601** to melt the solder paste **1605**.

The resistive solder assembly **1600** of FIG. **16** provides one of the significant advantages offered by embodiments of the disclosure. This advantage is that the honeycomb structure can be formed using only a single reflow process. Turning now to FIG. **17**, recall that the first ends (**1305,1306,1307,1308**) of the substrate bridging members **1301,1302,1303,1304** have been soldered to the solder pads (**1206,1207,1208,1209**) by a reflow process. The second circuit substrate **1500** is then aligned with the first circuit substrate **1200** such that the perimeter defined by the plurality of resistive solder assemblies **1506,1507,1508,1509** will align with the perimeter defined by the substrate bridging members **1301,1302,1303,1304** about the electrical component **1204** along the z-axis **1701**.

When the first circuit substrate **1200** and the second circuit substrate **1500** are pressed together, the second ends **1705,1706,1707,1708** of the substrate bridging members **1301,1302,1303,1304** seat against the plurality of resistive solder assemblies **1506,1507,1508,1509**. When current is passed through the plurality of resistive solder assemblies **1506,1507,1508,1509**, it will cause solder paste (**1605**) disposed on the plurality of resistive solder assemblies **1506,1507,1508,1509** to solder the second ends **1705,1706,1707,1708** of the substrate bridging members **1301,1302,1303,1304** to bond to the second major face **1502** of the second circuit substrate **1500** via a resistive heat soldering process.

Were the plurality of resistive solder assemblies **1506,1507,1508,1509** not used, reflowing the assembly in an attempt to cause solder paste (**1605**) disposed on the plurality of resistive solder assemblies **1506,1507,1508,1509** to solder the second ends **1705,1706,1707,1708** of the substrate bridging members **1301,1302,1303,1304** may risk dislodging the electrical components **1503,1504,1505** from the second major face **1502** of the second circuit substrate **1500**. Additionally, the fact that a second reflow process is not required to attach the second circuit substrate **1500** to the second ends **1705,1706,1707,1708** of the substrate bridging members **1301,1302,1303,1304**, embodiments of the disclosure advantageously provide for tighter tolerances along the z-axis **1701**. Said differently, the distance between the first substrate **1200** and the second circuit substrate **1500** along the z-axis **1701** can be more tightly controlled using the resistive solder assemblies **1506,1507,1508,1509** than with a second reflow process. The tolerances can be even tighter when the assembly is placed in a fixture during the attachment of the first substrate **1200** to the second circuit substrate **1500**, as the fixture can precisely align the first substrate **1200** and the second circuit substrate **1500** while the resistive solder assemblies **1506,1507,1508,1509** heat. The resulting circuit assembly **1800** is shown in FIG. **18**.

As shown in FIG. **18**, the circuit assembly **1800** comprises the first circuit substrate **1200** and the second circuit substrate **1500**. The first circuit substrate **1200** defines a first side of the circuit assembly **1800**, while the second circuit substrate **1500** defines a second side of the circuit assembly **1800**. At least one electrical component is disposed on at least one of the first circuit substrate **1200** or the second circuit substrate **1500** interior **1801** to the circuit assembly **1800**. In this

13

embodiment, electrical components are disposed on both major faces of the first circuit substrate **1200** and both major faces of the second circuit substrate **1500**. As shown, one or more unitary shield elements, in this embodiment the substrate bridging members **(1301),(1302),1303,1304**, are disposed interior **1802,1803** to the circuit assembly **1800** and have a first end soldered to the first circuit substrate **1200** and a second end soldered to the second circuit substrate **1500**. Each substrate bridging member **(1301),(1302),1303,1304**, defines a unitary structure having a first end bonded to the first major face **1201** and a second end bonded to the second major face **(1502)** to bridge the first circuit substrate **1200** and the second circuit substrate **1500**. As noted in the discussion of FIGS. **12-17**, in this illustrative embodiment at least one substrate bridging member, e.g., substrate bridging member **1304**, has a first end bonded to the solder pad **(1209)** on one major face and a second end bonded to a resistive solder assembly **(1509)** to bridge the first circuit substrate **1200** and the second circuit substrate **1500**.

In this embodiment, the plurality of substrate bridging members **(1301),(1302),1303,1304**, are disposed across the first major face **1201** of the first circuit substrate **1200** and the second major face **(1502)** of the second circuit substrate **1500** to orient the first circuit substrate **1200** substantially parallel to the second circuit substrate **1500**. As will be seen in the discussion of FIG. **22**, the circuit substrates need not always be parallel at all points. However, in this embodiment, the entirety of the first circuit substrate **1200** is substantially parallel with the entirety of the second circuit substrate **1500**. The term “substantially” is used to mean a dimension or orientation that is inclusive of manufacturing tolerances. Accordingly, where the substrate bridging members **(1301),(1302),1303,1304**, are to be the same height, but have manufacturing tolerances that make them slightly different heights, they will still orient the first circuit substrate **1200** and the second circuit substrate **1500** in a substantially parallel orientation.

Turning now to FIG. **19**, illustrated therein is an alternate circuit assembly **1900**, shown both assembled and in an exploded view. As noted above, any number of shield elements can be disposed along a substrate to provide electromagnetic shielding and/or mechanical support. In FIG. **19**, a network **1903** of shield elements is disposed between a first substrate **1901** and a second substrate **1902**. The network **1903** of shield elements can be a plurality of independent, unitary shield elements that are placed on the first substrate **1901** as previously described in one embodiment. Alternatively, in another embodiment independent, unitary shield elements can be attached to each other to form the network **1903** prior to placing the network **1903** on the first substrate **1901**.

The circuit assembly **1900** of FIG. **19** comprises the first substrate **1901**, which defines a first side of the circuit assembly **1900** and the second substrate **1902**, which defines a second side of the circuit assembly **1900**. At least one electrical component **1904** is disposed on at least one of the first substrate **1901** or the second substrate **1902** interior to the circuit assembly **1900**. Additionally, the network **1903** of shield elements comprises one or more unitary shield elements disposed interior to the circuit assembly **1900** and having a first end soldered to the first substrate **1901** and a second end soldered to the second substrate **1902**. The circuit assembly **1900** of FIG. **19** allows a designer to “stack” substrates “back-to-back” to get a density increase within an electronic device into which the circuit assembly **1900** is placed. At the same time, the network **1903** of shield elements, which resembles a true honeycomb in this embodi-

14

ment, provides an improved and advantageous mechanical structure that is resistant to damage from externally applied mechanical forces.

Where one of the first substrate **1901** or the second substrate **1902** includes resistive solder assemblies **(1600)**, the circuit assembly **1900** of FIG. **19** is also easily manufacturable. This is true despite the large number of shield elements forming the network **1903**. When using resistive solder assemblies **(1600)**, rather than using multiple reflow processes or many cumbersome hot plates in manufacture, one simply applies a current to the resistive solder assemblies **(1600)** to cause the network **1903** of shield elements to solder to a substrate. The current can be applied through vias in one of the substrates for convenient and easy manufacture. The use of resistive solder assemblies **(1600)** is not the only way to manufacture the circuit assembly **1900**, however. Other methods will be obvious to those of ordinary skill in the art having the benefit of this disclosure. For example, if one wanted to use hot plates, they could apply heat to one of the substrates through hole openings in the substrate, through inductive or resistive heating methods, or by applying heat to thermally conductive traces running to solder pads on one of the substrates. It should be noted that when reworking the circuit assembly **1900** for service, one of the substrates may be removed in the same manner as it was placed.

Turning now to FIGS. **20-23**, illustrated therein are sectional views of alternate embodiments of circuit assemblies **2000,2100,2200** in accordance with one or more embodiments of the disclosure. Beginning with FIG. **20**, illustrated therein is a “basic” circuit assembly **2000**. As shown, a first substrate **2001** defines a first side of the circuit assembly **2000**. A second substrate **2002** defines a second side of the circuit assembly **2000**. Electrical components **2003,2004** are disposed along a major face **2005** of the second substrate **2002**. One or more substrate bridging members **2006** are disposed interior to the circuit assembly **2000** and have a unitary structure. A first end **2007** is soldered to the first substrate **2001** and a second end **2008** is soldered to the second substrate **2002**. As shown in this embodiment, at least one of the one or more substrate bridging members **2006** is disposed interior to the electrical components **2003,2004**. As noted above, the one or more substrate bridging members **2006** can be used to electromagnetically shield at least one of the electrical components **2003,2004**.

Turning now to FIG. **21**, illustrated therein is an alternate circuit assembly **2100**. As with FIG. **20**, a first substrate **2101** defines a first side of the circuit assembly **2100**. A second substrate **2102** defines a second side of the circuit assembly **2100**. Electrical components **2103,2104** are disposed along a major face **2105** of the second substrate **2102**. One or more substrate bridging members **2106** are disposed interior to the circuit assembly **2100** and have a unitary structure. A first end **2107** is soldered to the first substrate **2101** and a second end **2108** is soldered to the second substrate **2102**.

In this embodiment, one electrical component **2104** is taller than another electrical component **2103**. To further increase overall density of the circuit assembly **2100**, the first substrate **2101** defines a recess **2109** that receives at least a portion of electrical component **2104**. Said differently, at least a portion of the taller electrical component, i.e., electrical component **2104**, extends into the recess **2109**. In one or more embodiments, the recess **2109** allows the first substrate **2101** to effectively touch electrical component **2104** when the outer layer of the recess **2109** is insulating, e.g., fiberglass of a printed circuit board, due to the fact that there is no electrical connection between the recess **2109** and the electrical component **2204** in such an embodiment.



15

The recess **2109** can be formed in a variety of ways. In one embodiment, the recess **2109** is formed by removing material from the first substrate **2101** in areas corresponding to taller components, i.e., areas above electrical component **2104**. In another embodiment, layers of the first substrate **2101** can be cut out before it is assembled. Other methods will be obvious to those of ordinary skill in the art having the benefit of this disclosure.

Turning now to FIG. **22**, illustrated therein is yet another alternate circuit assembly **2200**. A first substrate **2201** defines a first side of the circuit assembly **2200**. A second substrate **2202** defines a second side of the circuit assembly **2200**. Electrical components **2203, 2204** are disposed along a major face **2205** of the second substrate **2202**. One or more substrate bridging members **2206, 2207, 2208** are disposed interior to the circuit assembly **2200** and each have a unitary structure. The ends of each substrate bridging member **2206, 2207, 2208** are coupled as before, with a first end soldered to the first substrate **2201** and a second end soldered to the second substrate **2202**.

As with FIG. **21**, one electrical component **2204** is taller than another electrical component **2203**. To further increase overall density of the circuit assembly **2200**, the first substrate **2201** defines a recess **2209** that receives at least a portion of electrical component **2204**.

In the embodiment of FIG. **22**, the first substrate **2201** is deformed in an outer region **2210**. In this embodiment, the first substrate **2201** is deformed to bond to the second substrate **2202** at the edge **2211** of the circuit assembly **2200**. At the same time, at least a portion **2212** of the first substrate **2201** and the second substrate **2202** are oriented substantially parallel.

The deformation can be achieved in a variety of ways. In one embodiment, the deformed substrate is heated and sent through a forming process to cause the deformation. Other methods will be obvious to those of ordinary skill in the art having the benefit of this disclosure. In one embodiment, the deformation is applied along only a single axis, or along parallel axes. For example, the edge **2211** of the circuit assembly **2200** shown in FIG. **22** has a corresponding edge on an opposite side. Both sides could be bent along axes running into the page. This would be an example of parallel axis deformation.

In one or more embodiments, this deformation serves a variety of functions. First, as will be described with reference to FIG. **37**, the deformed portion can allow an electronic device to have a form factor with rounded sides. Second, bonding the first substrate **2201** to the second substrate **2202** increases mechanical strength of the circuit assembly **2200** where it does the most good, i.e., at the edge **2211** of the circuit assembly **2200**. Using a conformal board generally allows more mechanical strength without affecting the overall mechanical design. Moreover, placing at least one vertical wall (substrate bridging member **2208**) on the outside of the circuit assembly **2200** increases strength as well. If someone drops an electronic device including the circuit assembly **2200** on its edge, energy will translate through the various substrate bridging members **2206, 2207, 2208** before it gets to more sensitive components, thereby reducing the chance for damage to those components.

Yet another advantage includes the elimination of connectors, flex circuits, or other interconnection devices between the first substrate **2201** and the second substrate **2202** in some embodiments. For example, in one embodiment, electrical conductors **2220** coupled to power or ground, or electrical conductors **2221** carrying data signals or analog signals, can be disposed in or on the layers forming the first substrate **2201**

16

and the second substrate **2202**. These electrical conductors **2220, 2221** can connect through a connection **2222** disposed at the edge **2211** of the circuit assembly **2200**, thereby eliminating the need to include flexible circuits, wires, connectors, or other power/data communication lines between the first substrate **2201** and the second substrate **2202**.

Turning now to FIG. **23**, illustrated therein is yet another circuit assembly **2300** configured in accordance with embodiments of the disclosure. A first substrate **2301** defines a first side of the circuit assembly **2300**. A second substrate **2302** defines a second side of the circuit assembly **2300**. Electrical components **2303, 2304, 2305, 2306** are disposed along major faces both substrates. One or more substrate bridging members **2307, 2308, 2309** are disposed interior to the circuit assembly **2300**. The ends of each substrate bridging member **2307, 2308, 2309** are coupled as before, with a first end soldered to the first substrate **2301** and a second end soldered to the second substrate **2302**.

As with FIG. **21**, one electrical component **2304** is taller than another electrical component **2303**. To further increase overall density of the circuit assembly **2300**, the first substrate **2301** defines a recess **2319** that receives at least a portion of electrical component **2304**.

Other electrical components **2305, 2306** are taller still. In this explanatory embodiment, the other electrical components **2305, 2306** are imagers that receive light through a lens. Accordingly, affording them a recess as with electrical component **2304** would not work. To accommodate these other electrical components **2305, 2306** without sacrificing density, both the first substrate **2301** and the second substrate **2302** each define an aperture **2311, 2312**. Electrical components **2305, 2306** can then extend through their corresponding apertures **2311, 2312**.

The illustrative embodiment of FIG. **23** also includes other components to form a more complete circuit assembly **2300**. In one embodiment, a display **2313**, operable with the circuit assembly **2300**, is attached to the first substrate **2301**. Additionally, a battery **2314**, also operable with the circuit assembly **2300**, is attached to the second substrate **2302** on a side of the circuit assembly opposite the display **2313**. These components can be attached to the substrates in a variety of ways. Illustrating by example, in one embodiment they are simply adhesively attached, such as by double sided adhesive. Other methods of attaching these components to the substrates will be obvious to those of ordinary skill in the art having the benefit of this disclosure. For example, thermal compression pads having adhesive sides can be disposed between the components, or spacers could be disposed between the components. In one embodiment, the result is a solid, laminated structure.

Note that while two circuit substrates **2301, 2302** are shown in FIG. **23** and other embodiments for ease of illustration, it should be noted that more substrates can be added with substrate bridging members disposed between the circuit assembly **2300** of FIG. **23** and those additional substrates. Three, four, five, or more substrates can be honeycombed together as needed by a particular application. Additionally, to create additional stability in a system, some components, such as the battery **2314** can be segmented with substrate bridging members interposed between the battery segments to add increased mechanical stability to the system.

Embodiments of the disclosure contemplate that once shield elements or substrate bridging members are incorporated into a circuit assembly, some of these shield elements or substrate bridging members can be used for functions other than simply shielding or providing mechanical support. Components can be placed on the vertical elements. Radiators or

17

antennas can be defined in the vertical elements. Connectors can be incorporated into the vertical elements. Acoustic devices can be incorporated into the vertical elements. This is just a few of the number of functions that can be assigned to the shield elements or substrate bridging members configured in accordance with embodiments of the disclosure. Turning now to FIGS. 24-30, illustrated are some examples. Other examples will be obvious to those of ordinary skill in the art having the benefit of this disclosure.

Beginning with FIG. 24, a circuit assembly 2400 includes a first substrate 2401 defining a first side of the circuit assembly 2400 and a second substrate 2402 defining a second side of the circuit assembly 2400. As with previous embodiments, one or more substrate bridging members 2403 are disposed interior to the circuit assembly 2400 and have a unitary structure with a first end soldered to the first substrate 2401 and a second end soldered to the second substrate 2402.

In this illustrative embodiment, a circuit element 2404 is disposed along at least one substrate bridging member 2403. The circuit element 2404 can be operable with electrical or electronic components disposed on one or more of the first substrate 2401 and the second substrate 2402. In this embodiment, for illustrative purposes, the circuit element 2404 is shown as a push button switch. However, it could be other elements as well. For example, the circuit element 2404 could be a light emitting diode, a sensor, or other components.

Turning to FIGS. 25-26, a circuit assembly 2500 includes a first substrate 2501 defining a first side of the circuit assembly 2500 and a second substrate 2502 defining a second side of the circuit assembly 2500. As with previous embodiments, one or more substrate bridging members 2503 are disposed interior to the circuit assembly 2500 and have a unitary structure with a first end soldered to the first substrate 2501 and a second end soldered to the second substrate 2502.

In this illustrative embodiment, another circuit element 2504 is disposed along at least one substrate bridging member 2503. The circuit element 2504 can be operable with electrical or electronic components disposed on one or more of the first substrate 2501 and the second substrate 2502. In this embodiment, for illustrative purposes, the circuit element 2504 is shown as an electrical connector 2505.

Turning to FIG. 27, a circuit assembly 2700 includes a first substrate 2701 defining a first side of the circuit assembly 2700 and a second substrate 2702 defining a second side of the circuit assembly 2700. As with previous embodiments, one or more substrate bridging members 2703 are disposed interior to the circuit assembly 2700 and have a unitary structure with a first end bonded to the first substrate 2701 and a second end bonded to the second substrate 2702.

In one or more embodiments, the substrate bridging member 2703 defines an electromagnetic radiating element. In this illustrative embodiment, the substrate bridging member 2703 defines a slot antenna 2704. The substrate bridging member 2703 could define other types of antennas as well, including conformal antennas, inverted antennas, inverted-F antennas, and so forth.

Turning to FIG. 28, a circuit assembly 2800 includes a first substrate 2801 defining a first side of the circuit assembly 2800 and a second substrate 2802 defining a second side of the circuit assembly 2800. As with previous embodiments, one or more substrate bridging members 2803 are disposed interior to the circuit assembly 2800 and have a unitary structure with a first end bonded to the first substrate 2801 and a second end bonded to the second substrate 2802.

As with FIG. 27, the substrate bridging member 2803 comprises an electromagnetic radiating element. However, the electromagnetic radiating element is configured differ-

18

ently. In this embodiment, another circuit substrate 2804 spans the substrate bridging member 2803. The other circuit substrate 2804 can be, in one embodiment, a flexible circuit substrate having flexible layers encapsulating, having disposed thereon, or combinations thereof, electrical conductors. An electromagnetic radiating element 2805, shown here as a conductive trace disposed along the other circuit substrate 2804, serves as the radiating element.

As an alternative to placing the another circuit substrate 2804 along the substrate bridging member 2803, in other embodiments the substrate bridging member 2803 can be manufactured from a non-conductive material, such as plastic. Were this the case in FIG. 28, the radiating element 2805 could be plated directly on the substrate bridging member 2803. Alternatively, the radiating element 2805 could comprise a wire that is insert molded into a plastic substrate bridging member 2803 in another embodiment.

Turning to FIG. 29, a circuit assembly 2900 includes a first substrate 2901 defining a first side of the circuit assembly 2900 and a second substrate 2902 defining a second side of the circuit assembly 2900. As with previous embodiments, one or more substrate bridging members 2903 are disposed interior to the circuit assembly 2900 and have a unitary structure with a first end bonded to the first substrate 2901 and a second end bonded to the second substrate 2902.

As with FIG. 28, the substrate bridging member 2903 comprises another circuit substrate 2914 spanning the substrate bridging member 2903. The other circuit substrate 2914 can be, in one embodiment, a flexible circuit substrate. In this illustrative embodiment, one or more circuit elements 2904, 2905, 2906, 2907 are disposed on the other circuit substrate 2914. In one embodiment, the one or more circuit elements 2904, 2905, 2906, 2907 comprises circuit components, and in particular are 0201 surface mount components that can be resistors, capacitors or other devices. The surface mount components are soldered to the other circuit substrate 2914 in this embodiment, and are electrically coupled to other components of the circuit assembly 2900 by one or more conductive traces 2908 and/or vias 2909. Note that the one or more conductive traces 2908 and/or vias 2909 can be used to electrically couple circuit components on the first substrate 2901 to other circuit components on the second substrate 2902 as well. Accordingly, using embodiments of the disclosure, a designer can actually place electrical components on six surfaces of a circuit assembly, rather than two as was the case with prior art circuit boards. In one or more embodiments, the other substrate 2914 is simply a coupler between the circuit substrates. In one embodiment, the other substrate 2914 is not attached to the substrate bridging member 2903; the substrate bridging member 2903 merely provides mechanical support for the other substrate 2914. In one embodiment, the other substrate 2914 is effectively a "curtain" between the first substrate 2901 and the second substrate 2902.

Turning now to FIG. 30, an interior cross section of one explanatory circuit assembly 3000 is shown. One or more substrate bridging members may be disposed exterior to the electrical components 3003, 3004 as previously described. Such one or more substrate bridging members are not shown in FIG. 30 for simplicity.

FIG. 30 provides an illustration of how density can be further increased in one or more circuit assemblies 3000 configured in accordance with one or more embodiments of the disclosure. In FIG. 30, the two electrical components 3003, 3004 are coupled to both the first substrate 3001 and the second substrate 3002. Electrical component 3003 is a "ball grid array" or "BGA" component having the at least one electrical component comprising a first ball grid array 3005

19

coupled to a major face of the first substrate **3001** and a second ball grid array **3006** coupled to a major face of the second substrate **3002**. Electrical component **3004** is not a BGA component, but likewise has a first side **3007** coupled to the first substrate **3001** and a second side **3008** coupled to the second substrate **3002**.

Coupling electrical components **3003,3004** to both substrates **3001,3002** offers several advantages. First and foremost, it increases density. Second, by coupling components to multiple substrates, mechanical strength and resistance to external forces is increased. Third, by establishing a predetermined distance between the first substrate **3001** and the second substrate **3002**, such as 1.5 millimeters, components can be designed to “fill up” that space to further increase density and mechanical strength. Looking farther down the road, parallel substrates set at a predetermined distance apart can standardize the industry so that components become tailored to that size to provide additional mechanical strength. Fourth, attaching components to multiple substrates can improve thermal performance. For example, hot electrical components are best cooled by conduction. Accordingly, if a hot component is coupled to two substrates, two surfaces are available to remove heat rather than one.

When the substrate bridging members or shield elements of the disclosure are incorporated into circuit assemblies configured in accordance with embodiments of the disclosure, they can function in many different ways. A few have been described above, including providing support for additional substrates, circuit elements, and electromagnetic radiators. However, there are still more functions that can be provided by the substrate bridging members or shield elements of the disclosure. Turning now to FIG. **31**, illustrated therein is an acoustic function.

In FIG. **31**, four substrate bridging members **3101,3102,3103,3109** form the sides of an acoustic enclosure for an acoustic radiator **3104**. In the illustrative embodiment of FIG. **31**, the acoustic radiator **3104** is shown as a port **3202** disposed along substrate bridging member **3109**. However, in other embodiments, where manufacturing techniques allow for sufficient reduction in size, the acoustic radiator **3104** can potentially be a loudspeaker or other acoustic device. In either embodiment, the structure becomes an acoustically radiating element **3100** and the substrate bridging members **3101,3102,3103,3109** define the side walls of an acoustic chamber **3108**.

Optionally, one or more ports **3105,3106,3107** can be included in one or more of the substrate bridging members **3101,3102,3103,3109**. The one or more ports **3105,3106,3107** can be used in a variety of ways. In one embodiment, the one or more ports **3105,3106,3107** can be used to tune the volume of the acoustic enclosure defined by the four substrate bridging members **3101,3102,3103,3109** and the circuit substrates that will be coupled above and below the four substrate bridging members **3101,3102,3103,3109**. The tuning occurs in accordance with principles used in conventional ported loudspeaker tuning. When this occurs, the one or more ports **3105,3106,3107** define another acoustic element. In another embodiment, the one or more ports **3105,3106,3107** can be used to access other volume spaces within a circuit assembly to increase the effective volume of the acoustic enclosure. Examples of this will be described below with reference to FIGS. **32-33**.

It should be noted that ports **3105,3106,3107** are optional. For example, in other embodiments, the acoustically radiating element **3100** may be portless, thereby transforming it into a closed enclosure (closed once substrates are placed atop and beneath the acoustically radiating element **3100**) for an acoustic radiator, be it a port, loudspeaker, or other device.

20

Turning with FIG. **32**, the acoustically radiating element **3100** of FIG. **31** is being coupled to a first substrate **3201**. A loudspeaker **3204** has been disposed on the substrate **3201**. In one embodiment, port **3202** can be used either to tune the volume of the acoustic chamber **3108**, or alternatively to emit sound responsive to the loudspeaker **3204**. The loudspeaker **3204** can emit sound **3131** upward into the acoustic chamber **3108**. This sound **3131** excites the acoustic chamber **3108** such that sound **3132** is emitted from the port **3202**.

In other embodiments, port **3202** is not present. To illustrate that port **3202** is optional, it has been drawn in dashed lines in FIG. **32**. Where port **3202** is absent, sound can be delivered from the system of FIG. **32** in a variety of ways. Illustrating by example, in one embodiment, the loudspeaker **3204** can emit sound **3130** through an aperture **3133** in the first substrate **3201**. In this embodiment, the acoustic chamber **3108** acts as a closed volume to tune the loudspeaker **3204**.

In one embodiment, the acoustically radiating element **3100** is disposed such that substrate bridging member **3102** abuts an opening of another chamber defined by substrate bridging members **3208,3209,3210**. In this manner, substrate bridging member **3102** defines one or more apertures as ports (**3105,3106,3107**) that take advantage of the chamber defined by substrate bridging members **3208,3209,3210** to increase the effective volume of the acoustic chamber **3108**. Accordingly, when a second circuit substrate is placed atop the assembly, the effective acoustic volume available to the acoustic radiator **3104** becomes the volume within the acoustically radiating element **3100** and within the substrate bridging members **3208,3209,3210** defining an adjacent volume.

The resulting assembly **3300** is shown in FIG. **33**. A second substrate would be placed atop this assembly **3300** to complete the circuit assembly. Note that where the substrate bridging members (**3101,3102,3103,3109,3208,3209,3210**) are being used as shields, the acoustic optimization can be done without compromising the shielding performance when ports (**3105,3106,3107**) are designed with dimensions that preclude the electromagnetic waves of interest from passing through.

Advantageously, the embodiment of FIGS. **32-33** provides acoustic usage of volume that would otherwise go unused in prior art designs. For audio performance in small electronic devices, a long-existing problem is maximizing the volume of acoustic chambers. Under prior art shields, many small components are placed, thereby leaving a lot of unused volume. In embodiments employing ports in the substrate bridging members, additional volume within a circuit assembly is accessed, which enhances the overall volume of the acoustic enclosure by using ports to get from “one honeycomb to the next” without losing shield performance.

There are other ways acoustically radiating elements can be configured. Turning to FIG. **34** illustrated is another example. In FIG. **34**, a circuit assembly **3400** includes a first substrate **3401** defining one side of the circuit assembly **3400** and a second substrate (not shown in FIG. **34** so that the interior of the circuit assembly **3400** can be seen) defines another side of the circuit assembly **3400**. One or more substrate bridging members **3402,3403,3404,3405,3406,3407,3408,3409,3410,3415** are disposed interior to the first substrate **3401** and the second substrate. In this explanatory embodiment, each substrate bridging member **3402,3403,3404,3405,3406,3407,3408,3409,3410,3415** defines a single element with a first end bonded to the first substrate **3401** and a second end bonded to the second substrate. Two acoustic chambers **3411,3412** are defined by the substrate bridging members

21

**3402,3403,3404,3405,3406,3407,3408,3409,3410, 3415.** In this illustrative embodiment, loudspeakers **3416,3417** emit sound in the two acoustic chambers **3411,3412** that define acoustic wave guides. One or more ports **3413,3414**, each defining an acoustic element, can be included in the substrate bridging members **3404** so that the acoustic wave guides can emit sound.

One main advantage offered by embodiments of the disclosure is the ability to build an electronic device as almost a completely sealed unit. The electrical components of the electronic device are almost like a potted, sealed, solid-state unit with a simple housing snapped about the outside. This reduces the cost of the housing. As noted above, in prior art electronic devices, there can be multiple screws and multiple pins. Assembly therefore takes a lot of time and allows many opportunities for error. With embodiments of the disclosure, the internal components are a simple “laminated lump.” A housing simply snaps about the lump. This is shown in FIG. 35.

A circuit assembly **3501** has a display **3502** adhesively attached to a first side **3504** of the circuit assembly **3501**. A battery **3503** is adhesively attached to a second side **3505** of the circuit assembly **3501**. The display **3502** and the battery **3503** are electrically coupled to circuit components of the circuit assembly **3501** in one or more embodiments. An optional lens **3506** can be attached to the display **3502** in one or more embodiments. The lens **3506** goes on the front. A plastic housing **3507** is disposed about the lens **3506**. The plastic housing **3507** attaches to the circuit assembly **3501** and a rear housing **3508** simply snaps on. In one or more embodiments, the plastic housing **3507** can be omitted. With this structure, the circuit components form a laminated lump and a manufacturer merely snaps a housing **3508** about the lump.

In prior art designs, users frequently purchase after market covers for their electronic devices. Instead, embodiments of the disclosure provide the laminated lump and let a purchaser—on a customized basis even—pick the housing **3508** that they desire. The housing **3508** can even be printed or decorated as desired. There are a variety of options for building the electronic device. Embodiments of the disclosure can completely eliminate the cost and the screws associated with prior art designs. This is in addition to offering the user customization options that were not available previously. Embodiments of the disclosure allow for a “made to order” model for purchasing electronic devices. A purchaser simply goes to a kiosk, store, or on-line portal and picks the colors and patterns they want for the housing **3508** and a customized device is shipped to them. Retailers or marketers can order customized devices as well.

Turning now to FIG. 36, illustrated therein is one embodiment of an electronic device **3600** configured in accordance with one or more embodiments of the disclosure. The electronic device **3600** results when the elements of FIG. 35 are put together as previously described. The explanatory electronic device **3600** of FIG. 36 is shown as a smart phone for illustrative purposes. However, it will be obvious to those of ordinary skill in the art having the benefit of this disclosure that other electronic devices may be manufactured in accordance with embodiments of the disclosure as well. For example, the electronic device **3600** may be configured as a palm-top computer, a tablet computer, a gaming device, wearable computer, a media player, or other device.

A user **3613** is holding the electronic device **3600**. The operating system environment, which is configured as executable code operating on one or more processors or control circuits of the circuit assembly (**3501**), has associated there-

22

with various applications or “apps.” Examples of such applications shown in FIG. 36 include a cellular telephone application **3602** for making voice telephone calls, a web browsing application **3605** configured to allow the user **3613** to view webpages on the display assembly **3601** of the electronic device **3600**, an electronic mail application **3606** configured to send and receive electronic mail, a shopping application **3607** configured to permit a user to shop for goods and services online, and a camera application **3608** configured to capture still (and optionally video) images. These applications are illustrative only, as others will be obvious to one of ordinary skill in the art having the benefit of this disclosure.

As shown in FIG. 37, the circuit assembly **2100** described above with reference to FIG. 21 can be used to form a curved housing **3701** on the back side of the electronic device **3600**. As shown, the curved housing **3701** can include various features, including a camera **3702**. The camera **3702** can be one of the imagers (**2306**) of FIG. 23 when the circuit assembly (**2300**) having one or more apertures (**2311**) is employed. Other features include a speaker port **3703**. The speaker port **3703** can provide access to any of the acoustic radiators previously described.

Turning now to FIG. 38, illustrated therein is a method **3800** of constructing a circuit assembly in accordance with one or more embodiments. At step **3801**, a first substrate is provided. In one embodiment, the first substrate defines a first major face. At step **3802**, a second substrate is provided. In one embodiment, the second substrate defines a second major face.

At step **3803**, a plurality of electrical components is disposed on one or more of the first major face or the second major face. At step **3804**, one or more substrate bridging members are disposed on one of the first major face or the second major face. In one embodiment, each substrate bridging member defines a unitary structure having a first end and a second end. At step **3805**, the first end is bonded to the first major face and a second end is bonded to the second major face to bridge the first circuit substrate and the second circuit substrate. In one embodiment, the first end is bonded by soldering in a reflow process. In one embodiment, the second end is bonded by soldering with a resistive heat process.

Turning now to FIG. 39, illustrated therein is another method **3900** for manufacturing a circuit assembly in accordance with one or more embodiments of the disclosure. At step **3901**, a first substrate is provided. At step **3902** a second substrate is provided. At step **3903**, one or more substrate bridging members are disposed interior to the first substrate and the second substrate. In one embodiment, the one or more substrate bridging members have a unitary structure. At step **3904**, a first end of the one or more substrate bridging members is soldered to the first substrate. At step **3905**, a second end is soldered to the second substrate. Accordingly, the first substrate defines a first side of the circuit assembly formed at steps **3903-3904** and the second substrate defining a second side of the circuit assembly. In one embodiment, a circuit element may be disposed along at least one substrate bridging member at step **3906**.

Turning now to FIG. 40, illustrated therein are various embodiments of the disclosure. At **4001**, a circuit assembly, comprises a first circuit substrate defining a first major face and a second circuit substrate defining a second major face. At **4001**, a plurality of electrical components is disposed on one or more of the first major face or the second major face. At **4001**, the circuit assembly comprises one or more substrate bridging members. At **4001**, each substrate bridging member defines a unitary structure having a first end bonded to the first

23

major face and a second end bonded to the second major face to bridge the first circuit substrate and the second circuit substrate.

At **4002**, the one or more substrate bridging members of **4001** electromagnetically shield at least one of the plurality of electrical components. At **4003**, the one or more substrate bridging members of **4001** comprise metal.

At **4004**, the first end of **4001** is soldered to the first major face and the second end of **4001** is soldered to the second major face. At **4005**, the first end of **4004** is soldered by a reflow process and the second end of **4004** is soldered by a resistive heat process.

At **4006**, at least one substrate bridging member of **6003** defines a non-linear bridge wall. At **4007**, at least one substrate bridging member of **4001** is disposed interior to at least one electrical component. At **4008**, the one or more substrate bridging members of **4001** comprise a plurality of substrate bridging members defining a perimeter about at least one electrical component. At **4009**, one or more of the first circuit substrate or the second circuit substrate of **4008** comprise a ground plane interior to the perimeter.

At **4010**, the one or more substrate bridging members of **4001** comprise a plurality of substrate bridging members disposed across the first major face and the second major face to orient the first circuit substrate substantially parallel to the second circuit substrate. At **4011**, at least one electrical component of **4001** is coupled to one of the first circuit substrate or the second substrate. At **4011**, another of the first circuit substrate or the second circuit substrate defines a recess. At **4011**, at least a portion of the at least one electrical component of **4001** extends into the recess.

At **4012**, at least one of the first circuit substrate or the second circuit substrate of **4001** is deformed. At **4013**, the at least one of the first circuit substrate or the second substrate of **4012** is deformed to bond to at least another of the first circuit substrate or the second circuit substrate. At **4013**, at least a portion of the first circuit substrate and the second circuit substrate of **4012** is substantially parallel to the other.

At **4014**, at least one electrical component of **4001** is electrically coupled to both the first major face and the second major face. At **4015**, at least some of the plurality of electrical components at **4001** are disposed on two major faces of the first circuit substrate and two other major faces of the second circuit substrate.

At **4016**, a circuit assembly comprises a first circuit substrate defining a first major face and a second circuit substrate defining a second major face. At **4016**, one or more electrical components are coupled to one or more of the first circuit substrate or the second circuit substrate. At **4016**, the circuit assembly of **4016** comprises one or more substrate bridging members. At **4016**, one of the first circuit substrate or the second circuit substrate of **4016** comprises comprising a solder pad aligned with a resistive element. At **4016**, the solder pad is to heat when current is applied to the resistive element. At **4016**, at least one substrate bridging member of **4016** has a first end bonded to the solder pad and a second end bonded to another of the first major face or the second major face to bridge the first circuit substrate and the second circuit substrate. At **4017**, the solder pad and the resistive element of **4016** is integral to the first circuit substrate or the second circuit substrate.

At **4018**, a circuit assembly comprises a first substrate defining a first side of the circuit assembly and a second substrate defining a second side of the circuit assembly. At **4018**, at least one electrical component is disposed on at least one of the first substrate or the second substrate interior to the circuit assembly. At **4018**, one or more unitary shield ele-

24

ments are disposed interior to the circuit assembly and have a first end soldered to the first substrate and a second end soldered to the second substrate.

At **4019**, the circuit assembly of **4018** comprises a display, operable with the circuit assembly, attached to one of the first substrate or the second substrate exterior to the circuit assembly. At **4019**, the circuit assembly of **4018** comprises a battery, operable with the circuit assembly, attached to another of the first substrate or the second substrate on a side of the circuit assembly opposite the display.

At **4020**, at least one of the first substrate or the second substrate of **4018** defines an aperture. At **4020**, the circuit assembly of **4018** comprises an electrical component disposed on another of the first substrate or the second substrate, the electrical component extending through the aperture.

Turning now to FIG. **41**, illustrated therein are various embodiments of the disclosure. At **4101**, a circuit assembly comprises a first substrate defining a first side of the circuit assembly and a second substrate defining a second side of the circuit assembly. At **4101**, one or more substrate bridging members are disposed interior to the circuit assembly and have a unitary structure with a first end soldered to the first substrate and a second end soldered to the second substrate. At **4101** a circuit element is disposed along at least one substrate bridging member.

At **4102**, the circuit element of **4101** comprises a push button switch. At **4103**, the circuit element of **4101** comprises an electrical connector.

At **4104**, the circuit assembly of **4101** comprises another circuit substrate spanning the at least one substrate bridging member. At **4104**, the circuit element of **4101** is disposed on the another circuit substrate. At **4105**, the circuit element of **4101** comprises a circuit component. At **4106**, the circuit component of **4105** comprises a surface mount circuit component soldered to the another circuit substrate. At **4107**, the another circuit substrate of **4104** comprises a flexible substrate.

At **4108**, a circuit assembly comprises a first substrate defining one side of the circuit assembly and a second substrate defining another side of the circuit assembly. At **4108**, one or more substrate bridging members are disposed interior to the first substrate and the second substrate. At **4108**, each substrate bridging member has a unitary structure with a first end bonded to the first substrate and a second end bonded to the second substrate. At **4108** at least one substrate bridging member defines a radiating element.

At **4109**, the radiating element of **4108** comprises an electromagnetically radiating element. At **4110**, the electromagnetically radiating element of **4109** comprises a slot antenna. At **4111**, the circuit assembly of **4109** comprises another circuit substrate spanning the at least one substrate bridging member. At **4111**, the electromagnetically radiating element of **4109** is disposed on the another circuit substrate.

At **4112**, the radiating element of **4108** comprises an acoustically radiating element. At **4113**, the acoustically radiating element of **4108** comprises a loudspeaker. At **4114**, the acoustically radiating element of **4108** comprises a port.

At **4115**, the circuit assembly of **4108** comprises a circuit element disposed along at least another substrate bridging member. At **4116**, the circuit assembly of **4108** comprises at least one circuit element coupled to both the first substrate and the second substrate.

At **4117**, a circuit assembly comprises a first substrate defining one side of the circuit assembly and a second substrate defining another side of the circuit assembly. At **4117**, one or more substrate bridging members are disposed interior to the first substrate and the second substrate. At **4117** each

25

substrate bridging member defines a single element with a first end bonded to the first substrate and a second end bonded to the second substrate. At **4117**, at least one substrate bridging member defines an acoustic element.

At **4118**, the one or more substrate bridging members of **4117** define an acoustic chamber. At **4119**, the one or more substrate bridging members of **4118** define one or more apertures. At **4119**, the at least another substrate bridging member of **4118** defines one or more corresponding apertures. At **4119**, the one or more corresponding apertures are to increase a volume of the acoustic chamber. At **4020**, the acoustic chamber of **4018** defines an acoustic wave guide.

In the foregoing specification, specific embodiments of the present disclosure have been described. However, one of ordinary skill in the art appreciates that various modifications and changes can be made without departing from the scope of the present disclosure as set forth in the claims below. Thus, while preferred embodiments of the disclosure have been illustrated and described, it is clear that the disclosure is not so limited. Numerous modifications, changes, variations, substitutions, and equivalents will occur to those skilled in the art without departing from the spirit and scope of the present disclosure as defined by the following claims. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of present disclosure. The benefits, advantages, solutions to problems, and any element(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential features or elements of any or all the claims.

What is claimed is:

1. A circuit assembly, comprising:
  - a first circuit substrate defining a first major face;
  - a second circuit substrate defining a second major face;
  - an electrical component coupled to the second circuit substrate; and
  - at least one substrate bridging member disposed interior to a perimeter of the circuit assembly,
  - the at least one substrate bridging member defining a unitary structure having a first end coupled to the first major face; a second end coupled to the second major face, and a bridge wall extending between the first end and the second end, to bridge the first circuit substrate and the second circuit substrate, the first end extending substantially orthogonal to the bridge wall, the second end extending substantially orthogonal to the bridge wall.
2. The circuit assembly of claim 1, wherein the at least one substrate bridging member is configured to electrically shield the electrical component.
3. The circuit assembly of claim 1, wherein at least one substrate bridging member is composed entirely of metal.
4. The circuit assembly of claim 1, wherein the first end is soldered to the first major face and the second end is soldered to the second major face.
5. The circuit assembly of claim 4, wherein the first end is soldered by a reflow process, and the second end is soldered by a resistive heat process.
6. The circuit assembly of claim 1, wherein a portion of the bridge wall of the at least one substrate bridging member is non-linear.
7. The circuit assembly of claim 1, wherein the at least one substrate bridging member has a thickness in a range of about 0.15 millimeters to 0.2 millimeters.
8. The circuit assembly of claim 1, wherein the at least one substrate bridging member includes a plurality of substrate bridging members configured to surround the electrical com-

26

ponent, a portion of the first circuit substrate including a ground plane, wherein the ground plane and the plurality of substrate bridging members are configured to electrically shield the electrical component.

9. The circuit assembly of claim 1, wherein the at least one substrate bridging member includes a plurality of substrate bridging members arranged in a honeycomb structure.

10. The circuit assembly of claim 1, wherein the at least one substrate bridging member includes a plurality of substrate bridging members disposed across the first major face and the second major face to orient the first circuit substrate substantially parallel to the second circuit substrate.

11. The circuit assembly of claim 1, wherein a portion of the first circuit substrate defines a recess, a portion of the electrical component extending into the recess.

12. The circuit assembly of claim 1, wherein the first circuit substrate includes an outer curved portion that curves to an edge of the first circuit substrate, the second circuit substrate being coupled to the outer curved portion at the edge of the first circuit substrate.

13. The circuit assembly of claim 12, wherein the first circuit substrate includes a linear portion disposed adjacent to the outer curved portion, the linear portion being coupled to the first end of the at least one substrate bridging member.

14. The circuit assembly of claim 1, further comprising: a circuit element disposed along the bridge wall of the at least one substrate bridging member.

15. The circuit assembly of claim 14, wherein the circuit element includes a push button switch, or an electrical connector.

16. A circuit assembly, comprising:
 

- a first circuit substrate defining a first major face;
- a second circuit substrate defining a second major face;
- an electrical component coupled to the second circuit substrate; and
- at least one substrate bridging member disposed between the first major face and the second major face,
- the first circuit substrate including a solder pad aligned with a resistive element, the solder pad configured to heat when current is applied to the resistive element,
- the at least one substrate bridging member having a first end coupled to the solder pad, a second end coupled to the second major face, and a bridge wall extending between the first end and the second end, to bridge the first circuit substrate and the second circuit substrate, the first end extending substantially orthogonal to the bridge wall, the second end extending substantially orthogonal to the bridge wall.

17. The circuit assembly of claim 16, wherein the solder pad and the resistive element are integral to the first circuit substrate.

18. A circuit assembly, comprising:
 

- a first substrate defining a first side of the circuit assembly;
- a second substrate defining a second side of the circuit assembly;
- an electrical component disposed on the second substrate interior to the circuit assembly; and
- a plurality of substrate bridging members disposed between the first side and the second side, each of the plurality of substrate bridging members including a first end coupled to the first side, a second end coupled to the second side, and a bridge wall extending between the first end and the second end, the first end extending substantially orthogonal to the bridge wall in a first direction away from the bridge wall, the second end extending substantially orthogonal to the bridge wall in

27

a second direction away from the bridge wall, the second direction being opposite to the first direction.

**19.** The circuit assembly of claim **18**, further comprising:

a display, operable with the circuit assembly, attached to one of the first substrate or the second substrate exterior 5 to the circuit assembly; and

a battery, operable with the circuit assembly, attached to another of the first substrate or the second substrate on a side of the circuit assembly opposite the display.

**20.** The circuit assembly of claim **18**, wherein the first 10 substrate defines an aperture, and the aperture receives a portion of the electrical component.

\* \* \* \* \*

28